Geology

Senior High

Grade 12

Teacher Guide

Standards-Based

Papua New Guinea

Department of Education

‘FREE ISSUE
NOT FOR SALE’

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Contents

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Acronyms

AAL	Assessment As Learning
AFL	Assessment For Learning
AOL	Assessment Of Learning
BoS	Board of Studies
CDD	Curriculum Development Division
CP	Curriculum Panel
CRS	Classroom Response System
DA	Diagnostic Assessment
HOD	Head of Department
IHD	Integral Human Development
MTDG	Medium Term Development Goal
NGO	Non-Government Organisation
PBA	Performance Based Assessment
PNG	Papua New Guinea
SAC	Subject Advisory Committee
SBC	Standards Based Curriculum
SBE	Standards Based Education
SCG	Subject Curriculum Group
SRS	Student Response System
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics

Secretary's Message

The aims and goals of the SBC identify the important knowledge, skills, values, and attitudes that all students are expected to acquire and master in order to effectively function in society and actively contribute to its development, students' welfare and enable them to acquire and apply 21st Century knowledge, skills, values, and attitudes in their life after Grade 12.

The basic knowledge of Geology is essential to meeting the environmental challenges and natural resource limitations of the twenty-first Century. It is critical that earth-science education begin at the kindergarten level and include advanced offerings at the secondary school level, and that highly qualified earth-science teachers provide the instruction.

Geology is an integrated science, including biology, chemistry, and physics as they apply to the workings of Earth. The applied, and often visual, nature of earth science helps learners see its relevance to their lives and to their communities. Engaging students in learning about Earth supports the development of problem solving, analytical and critical thinking skills and at the same time highlights the importance of Science, Technology, Engineering, Arts and Math (STEAM) careers to society.

This is a critical time for students to understand how Earth works as a system and how humans interact with Earth. Understanding the causes and potential societal consequences of natural Earth processes and the production, availability, and potential depletion of natural resources is of particular importance.

Empowering students with scientific knowledge and skills to make informed decisions as citizens is a vital undertaking and a key responsibility for science educators, geoscientists and all citizens.

I encourage teachers to read each section of the guide carefully and become familiar with the content of the subject specified in this guide. I also encourage teachers to try out your own ideas, strategies and available resources that you believe will effectively work in your schools for your students.

I commend and approve this Grade 12 Geology Teacher Guide to be used in all Senior High Schools throughout Papua New Guinea.

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UKE W. KOMBRA, PhD
Secretary for Education

Introduction

In its broadest sense, geology is the study of Earth – its interior and its exterior surface, the rocks and other materials that are around us, the processes that have resulted in the formation of those materials, the water that flows over the surface and lies underground, the changes that have taken place over the vastness of geological time, and the changes that we can anticipate will take place in the near future.

Geology is a science, meaning that students will use deductive reasoning and scientific methods to understand geological problems. It is arguably, the most integrated of all the sciences because it involves the understanding and application of all of the other sciences: physics, chemistry, biology, mathematics, astronomy, and others. But unlike most of the other sciences, geology has an extra dimension, that of time – deep time – billions of years of it.

This Grade 12 Geology Teacher Guide was developed as a support document for the implementation of Grade 12 Geology Syllabus. It contains useful information that you should read and familiarise yourself with before you plan and teach the subject. The guidelines provided are translated from the content standards prescribed in the syllabus into teachable content. The suggested teaching and learning strategies given will assist you to plan quality and interactive science lessons based on the knowledge, skills, attitudes and values from the benchmarks.

The teacher guide also contains samples of assessment tasks and rubrics that will help you to design quality assessments to measure students' performance against the intended content standards and evidence outcomes. The learning activities prepared must engage and motivate your students to think critically and communicate ideas freely with other students in their class.

The Grade 12 Geology is timetabled for **240** minutes per week.

Structure of the Teacher Guide

There are four main components to this teacher guide. They provide essential information on what all teachers should know and do to effectively implement the Geology curriculum.

Part 1 provides generic information to help the teachers to effectively use the teacher guide and the syllabus to plan, teach and assess students' performance and proficiency on the national content standards and grade-level benchmarks. The purpose of the teacher guide, syllabus and teacher guide alignment, and the four pillars of PNG SBC, which are morals and values education, cognitive and high level thinking, and 21st Century thinking skills, STEAM, and core curriculum. There are explained to inform as well as guide the teachers so that they align SBE/SBC aims and goals, overarching and SBC principles, content standards, grade-level benchmarks, learning objectives and best practice when planning lessons, teaching, and assessing students.

Part 2 provides information on the strands, units, topics and learning objectives. How topics and learning objectives are derived is explained to the teachers to guide them to use the learning objectives provided for planning, instruction and assessment. Teachers are encouraged to develop additional topics and learning objectives to meet the learning needs of their students and communities where necessary.

Part 3 provides information on SBC planning to help guide the teachers when planning SBC lessons. Elements and standards of SBC lesson plans are described as well as how to plan for underachievers, use evidence to plan lessons, and use differentiated instruction, amongst other teaching and learning strategies.

Part 4 provides information on standards-based assessment, inclusive of performance assessment and standards, standards-based evaluation, standards-based reporting, and standards-based monitoring. This information should help the teachers to effectively assess, evaluate, report and monitor demonstration of significant aspects of a benchmark.

The above components are linked and closely aligned. They should be connected to ensure that the intended learning outcomes and the expected quality of education standards are achieved. The close alignment of planning, instruction and assessment is critical to the attainment of learning standards.

Purpose of the Teacher Guide

This teacher guide describes what all teachers should know and do to effectively plan, teach, and assess Grade 12 Geology content to enable all students to attain the required learning and proficiency standards. The overarching purpose of this teacher guide is to help teachers to effectively plan, teach, assess, evaluate, report and monitor students' learning and mastery of national and grade-level expectations. That is, the essential knowledge, skills, values and attitudes (KSVAs) described in the content standards and grade-level benchmarks, and their achievement of the national and grade-level proficiency standards.

Ample information with thorough guidelines is provided for the teacher to use to achieve the essential KSVAs embedded in the set national content standards and grade level benchmarks.

Thus, the teacher is expected to;

- understand the significance of aligning all the elements of Standards-Based Curriculum (SBC) as the basis for achieving the expected level of education quality,
- effectively align all the components of SBC when planning, teaching, and assessing students' learning and levels of proficiency,
- effectively translate and align the Geology syllabi and teacher guide to plan, teach and assess different Geology units and topics, and the KSVAs described in the grade-level benchmarks,
- understand the Geology national content standards, grade-level benchmarks, and evidence outcomes,
- effectively make sense of the content (KSVAs) described in the Geology national content standards and the essential components of the content described in the grade-level benchmarks;
- effectively guide students to progressively learn and demonstrate proficiency on a range of Geology skills, processes, concepts, ideas, principles, practices, values and attitudes,
- confidently interpret, translate and use Geology content standards and benchmarks to determine the learning objectives and performance standards, and plan appropriately to enable all students to achieve these standards,
- embed the core curriculum in their Geology lesson planning, instruction, and assessment to permit all students to learn and master the core KSVAs required of all students,

- provide opportunities for all students to understand how STEAM has and continues to shape the social, political, economic, cultural, and environment contexts and the consequences, and use STEAM principles, skills and process,

- integrate cognitive skills (critical, creative, reasoning, decision-making, and problem-solving skills), high level thinking skills (analysis, synthesis and evaluation skills), values (personal, social, work, health, peace, relationship, sustaining values), and attitudes in lesson planning, instruction and assessment;

- meaningfully connect what students learn in Geology with what is learnt in other subjects to add value and enhance students' learning so that they can integrate what they learn and develop in-depth vertical and horizontal understanding of subject content,

- formulate effective SBC lesson plans using learning objectives identified for each of the topics,

- employ SBC assessment approaches to develop performance assessments to assess students' proficiency on a content standard or a component of the content standard described in the grade-level benchmark and

- effectively score and evaluate students' performance in relation to a core set of learning standards or criteria, and make sense of the data to ascertain students' status of progress towards meeting grade-level and nationally expected proficiency standards, and use evidence from the assessment of students' performance to develop effective evidence-based intervention strategies to help students' making inadequate or slow progress towards meeting the grade-level and national expectations to improve their learning and performance.

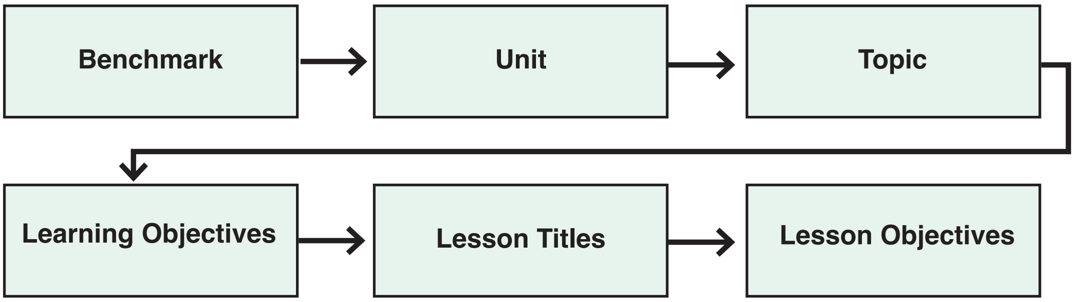
How to use the Teacher Guide

Teacher Guide provides essential information about what the teacher needs to know and do to effectively plan, teach and assess students learning and proficiency on learning and performance standards. The different components of the teacher guide are closely aligned with SBC principles and practice, and all the other components of PNG SBC. It should be read in conjunction with the syllabus in order to understand what is expected of teachers and students to achieve the envisaged quality of education outcomes.

The first thing teachers should do is to read and understand each of the sections of the teacher guide to help them understand the key SBC concepts and ideas, alignment of PNG SBC components, alignment of the syllabus and teacher guide, setting of content standards and grade-level benchmarks, core curriculum, STEAM, curriculum integration, essential knowledge, skills, values and attitudes, strands, units and topics, learning objectives, SBC lesson planning, and SBC assessment. A thorough understanding of these components will help teachers meet the teacher expectations for implementing the SBC curriculum, and therefore the effective implementation of Grades 11 and 12 Geology Curriculum. Based on this understanding, teachers should be able to effectively use the teacher guide to do the following:

Determine Lesson Objectives and Lesson Titles

Units, topics and learning objectives have been identified and described in the Teacher Guide and Syllabus. Learning objectives are derived from topics that are extracted from the grade-level benchmarks. Lesson titles are deduced from the learning objectives. Teachers should familiarise themselves with this process as it is essential for lesson planning, instruction and assessment. However, depending on the context and students' learning abilities, teachers would be required to determine additional lesson objectives and lesson titles Teachers should use the examples provided in this teacher guide to formulate additional lesson objectives and lesson titles to meet the educational or learning needs of their students. What is provided here is not exhaustive.



Identify and Teach Grade Appropriate Content

Grade appropriate content has been identified and scoped and sequenced using appropriate content organisation principles. The content is sequenced using the spiraling sequence principles. This sequencing of content will enable students to progressively learn the essential knowledge, skills, values and attitudes as they progress further into their schooling. What students learn in previous grades is reinforced and deepens in scope with an increase in the level of complexity and difficulty in the content and learning activities.

It is important to understand how the content is organised so that grade appropriate content and learning activities can be selected, if not already embedded in the benchmarks and learning objectives, to not only help students learn and master the content, but ensure that what is taught is rigorous, challenging, and comparable.

Integrate the Core Curriculum in Lesson Planning, Instruction and Assessment

Teachers should use this teacher guide to help them integrate the core curriculum – values, cognitive and high level skills, 21st Century skills, STEAM principles and skills, and reading, writing, and communication skills in their lesson planning, instruction and assessment. All students in all subjects are required to learn and master these skills progressively through the education system.

Integrate Cognitive, High Level, and 21st Century Skills in Lesson Planning, Instruction and Assessment

Teachers should integrate the cognitive, high level and 21st Century skills in their annual teaching programs, and give prominence to these skills in their lesson preparation, teaching and learning activities, performance assessment, and performance standards for measuring students' proficiency on these skills. Science addresses the skills and processes of sensitive, moral, ethical and environmental issues in the physical world and global industries. Thus, students will be able to make informed decisions, problem – solving and management knowledge, skills, values and attitudes in Science. This enables them to function effectively in the work and higher education environments as productive and useful citizens of a culturally diverse and democratic society in an interdependent world.

In addition, it envisaged all students attaining expected proficiency levels in these skills and will be ready to pursue careers and higher education academic programs that demand these skills, and use them in their everyday life after they leave school at the end of Grade 12. Teachers should use the teacher guide to help them to effectively embed these skills, particularly in their lesson planning and in the teaching and learning activities as well as in the assessment of students' application of the skills.

Integrate Science Values and Attitudes in Lesson Planning, Instruction and Assessment

In sciecne, students are expected to learn, promote and use work, relationship, peace, health, social, personal, family, community, national and global values in the work and study environments as well as in their conduct as community, national and global citizens. Teachers should draw from the information and suggestions provided in the syllabus and teacher guide to integrate values and attitudes in their lesson planning, instruction, and assessment. They should report on students' progression towards internalizing different values and attitudes and provide additional support to students who are yet to reach the internalization stage to make positive progress towards this level.

Integrate Science, Technology, Engineering, Arts and Mathematics (STEAM) Principles and Skills in Lesson Planning, Instruction and Assessment

Teachers should draw from both the syllabus and teacher guide in order to help them integrate STEAM principles and skills, and methodologies in their lesson planning, instruction and assessment. STEAM teaching and learning happens both inside and outside of the classroom. Effective STEAM teaching and learning requires both the teacher and the student to participate as core investigators and learners, and to work in partnership and collaboration with relevant stakeholders to achieve maximum results. Teachers should use the syllabus, teacher guides and other resources to guide them to plan and implement this and other innovative and creative approaches to STEAM teaching and learning to make STEAM principles and skills learning fun and enjoyable and, at the same time, attain the intended quality of learning outcomes.

Identify and Use Grade and Context Appropriate, Innovative, Differentiated and Creative Teaching and Learning Methodologies

SBC is an eclectic curriculum model. It is an amalgam of strengths of different curriculum types, including behavioural objectives, outcomes, and competency. Its emphasis is on students attaining clearly defined, measurable, observable and attainable learning standards, i.e., the expected level of education quality. Proficiency (competency) standards are expressed as performance standards/criteria and evidence outcomes, that is, what all students are expected to know (content) and do (application of content in real life or related situations) to indicate that they are meeting, have met or exceeded the learning standards. The selection of grade and contextually appropriate teaching and learning methodologies is critical to enabling all students to achieve the expected standard or quality of education. Teaching and learning methodologies must be aligned to the content, learning objective, and performance standard in order for the teacher to effectively teach and guide students towards meeting the performance standard for the lesson. They should be equitable and socially inclusive, differentiate, student-centred, and lifelong. They should enable STEAM principles and skills to be effectively taught and learned by students. Teachers should use the teacher guide to help them make informed decisions when selecting the types of teaching and learning methodologies to use in their teaching of the subject content, including STEAM principles and skills.

Plan Standards-Based Lessons

SBC lesson planning is quite difficult to do. However, this will be easier with more practice and experience over time. Effective SBC lesson plans must meet the required standards or criteria so that the learning objectives and performance standards are closely aligned to attain the expected learning outcomes. Teachers should use the guidelines and standards for SBC lesson planning and examples of SBC lesson plans provided in the teacher guide to plan their lessons. When planning lessons, it is important for teachers to ensure that all SBC lesson planning standards or criteria are met. If standards are not met, instruction will not lead to the attainment of intended performance and proficiency standards. Therefore, students will not attain the national content standards and grade-level benchmarks.

Use Standards-Based Assessment

Standards-Based Assessment has a number of components. These components are intertwined and serve to measure evaluate, report, and monitor students' achievement of the national and grade-level expectations, i.e., the essential knowledge, skills, values and attitudes they are expected to master and demonstrate proficiency on. Teachers should use the information and examples on standards-based assessment to plan, assess, record, evaluate, report and monitor students' performance in relation to the learning standards.

Make informed Judgments About Students' Learning and Progress Towards Meeting Learning Standards

Teachers should use the teacher guide to effectively evaluate students' performance and use the evidence to help students to continuously improve their learning as well as their classroom practice.

It is important that teachers evaluate the performance of students in relation to the performance standards and progressively the grade-level benchmarks and content standards to make informed judgments and decisions about the quality of their work and their progress towards meeting the content standards or components of the standards. Evaluation should not focus on only one aspect of students' performance. It should aim to provide a complete picture of each student's performance. The context, inputs, processes, including teaching and learning processes, and the outcomes should be evaluated to make an informed judgment about each student's performance, Teachers should identify the causal factors for poor performance, gaps in students learning, gaps in teaching, teaching and learning resource constraints, and general attitude towards learning. Evidence-based decisions can then be made regarding the interventions for closing the gaps to allow students to make the required progress towards meeting grade-level and national expectations.

Prepare Students' Performance Reports

Reporting of students' performance and progress towards the attainment of learning standards is an essential part of SBC assessment. Results of students' performance should be communicated to particularly the students and their parents to keep them informed of students' academic achievements and learning challenges as well as what needs to be done to enable the students' make positive progress towards meeting the proficiency standards and achieve the desired level of education quality. Teachers should use the information on the reporting of students' assessment results and the templates provided to report the results of students' learning.

Monitor Students' Progress Towards Meeting the National Content Standards and Grade-Level Benchmarks

Monitoring of student's progress towards the attainment of learning standards is an essential component of standards-based assessment. It is an evidence-based process that involves the use of data from students' performance assessments to make informed judgements about students' learning and proficiency on the learning standards or their components, identify gaps in students' learning and the causal factors, set clear learning improvement targets, and develop effective evidence-based strategies (including preplanning and re-teaching of topics), set clear timeframes, and identify measures for measuring students' progress towards achieving the learning targets.

Teachers should use the teacher guide to help them use data from students' performance assessments to identify individual students' learning weaknesses and develop interventions, in collaboration with each student and his/her parents or guardians, to address the weaknesses and monitor their progress towards meeting the agreed learning goals.

Develop additional Benchmarks

Teachers can develop additional benchmarks using the examples in the teacher guide to meet the learning needs of their students and local communities. However, these benchmarks will not be nationally assessed as these are not comparable. They are not allowed to set their own content standards or manipulate the existing ones. The setting of national content standards is done at the national level to ensure that required learning standards are maintained and monitored to sustain the required level of education quality.

Avoid Standardisation

The implementation of Science curriculum must not be standardised.
SBC does not mean that the content, lesson objectives, teaching and learning strategies, and assessment are standardised. This is a misconception and any attempt to standardise the components of curriculum without due consideration of the teaching and learning contexts, student's backgrounds and experiences, and different abilities and learning styles of students will be counterproductive. It will hinder students from achieving the expected proficiency standards and hence, high academic standards and the desired level of education quality. That is, they should not be applied across all contexts and with all students, without considering the educational needs and the characteristics of each context. Teachers must use innovative, creative, culturally relevant, and differentiated teaching and learning approaches to teach the curriculum and enable their students to achieve the national content standards and grade-level benchmarks. And enable all students to experience success in learning the curriculum and achieve high academic standards.

What is provided in the syllabus and teacher guide are not fixed and can be changed. Teachers should use the information and examples provided in the syllabus and the teacher guide to guide them to develop, select, and use grade, context, and learner appropriate content, learning objectives, teaching and learning strategies, and performance assessment and standards. SBC is evidence-based hence decisions about the content, learning outcomes, teaching and learning strategies, students' performance, and learning interventions should be based on evidence. Teaching and learning should be continuously improved and effectively targeted using evidence from students' assessment and other sources.

Syllabus and Teacher Guide Alignment

A teacher guide is a framework that describes how to translate the content standards and benchmarks (learning standards) outlined in the syllabus into units and topics, learning objectives, lesson plans, teaching and learning strategies, performance assessment, and measures for measuring students' performance (performance standards). It expands the content overview and describes how this content identified in the content standards and their components (essential KSVAs) can be translated into meaningful and evidence-based teaching topics and learning objectives for lesson planning, instruction and assessment. It also describes and provides examples of how to evaluate and report on students' attainment of the learning standards, and use evidence from the assessment of students' performance to develop evidence-based interventions to assist students who are making slow progress towards meeting the expected proficiency levels to improve their performance.

This subject comprises of the Syllabus and Teacher Guide. These two documents are closely aligned, complimentary and mutually beneficial.

They are the essential focal points for teaching and learning the essential Social Science knowledge, skills, values and attitudes.

Syllabus	Teacher Guide
Outlines the ultimate aim and goals, and what to teach and why teach it	**Describes how to plan, teach, and assess students' performance**
• Overarching and SBC principles • Content overview • Core curriculum • Essential knowledge, skills, values and attitudes • Strands and units • Evidence outcomes • Content standards and grade-level benchmarks • Overview of assessment, evaluation, and Reporting	• Determine topics for lesson planning, instruction and assessment • Formulate learning objectives • Plan SBC lesson plans • Select teaching and learning strategies • Implement SBC assessment and evaluation • Implement SBC reporting and monitoring

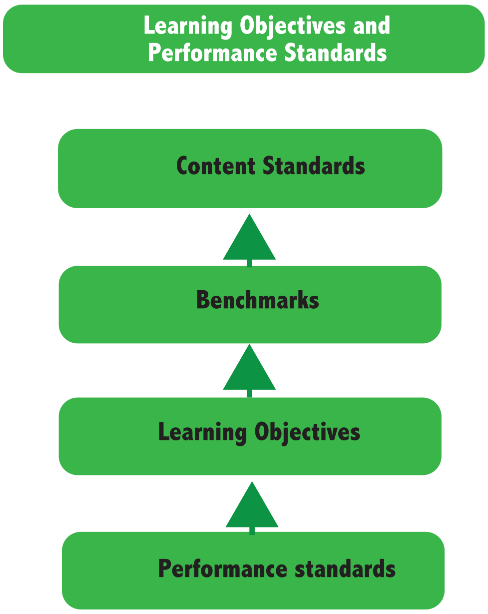
The syllabus outlines the ultimate aim and goals of SBE and SBC, what is to be taught and why it should be learned by students, the underlying principles and articulates the learning and proficiency standards that all students are expected to attain. On the other hand, the teacher guide expands on what is outlined in the syllabus by describing the approaches or the how of planning, teaching, learning, and assessing the content so that the intended learning outcomes are achieved.

This teacher guide should be used in conjunction with the syllabus. Teachers should use these documents when planning, teaching and assessing Grade 12 content.

Teachers will extract information from the syllabus (e.g., content standards and grade-level benchmarks) for lesson planning, instruction and is for measuring students' attainment a content standard as well as progress to the next grade of schooling.

Learning and Performance Standards Alignment

Content Standards, Benchmarks, Learning Objectives, and Performance Standards are very closely linked and aligned. There is a close linear relationship between these standards. Students' performance on a significant aspect of a benchmark (KSVA) is measured against a set of performance standards or criteria to determine their level of proficiency using performance assessment. Using the evidence from the performance assessment, individual student's proficiency on the aspect of the benchmark assessed and progression towards meeting the benchmark and hence the content standard are then determined.



Effective alignment of these learning standards and all the other components of PNG SBE and SBC (ultimate aim and goals, overarching, SBC and subject-based principles, core curriculum, STEAM, and cognitive, high level, and 21st Century skills) is not only critical but is also key to the achievement of high academic standards by all students and the intended level of education quality. It is essential that teachers know and can do standards alignment when planning, teaching, and assessing students' performance so that they can effectively guide their students towards meeting the grade-level benchmarks (grade expectations) and subsequently the content standards (national expectations).

Learning and Performance Standards

Standards-Based Education (SBE) and SBC are underpinned by the notion of quality. Standards define the expected level of education quality that all students should achieve at a particular point in their schooling. Students' progression and achievement of education standard(s) are measured using performance standards or criteria to determine their demonstration or performance on significant aspects of the standards and therefore their levels of proficiency or competency. When they are judged to have attained proficiency on a content standard or benchmark or components of these standards, they are then deemed to have met the standard(s) that is, achieved the intend level of education quality.

Content standards, benchmarks, and learning objectives are called learning standards while performance and proficiency standards (evidence outcomes) can be categorised as performance standards. These standards are used to measure students' performance, proficiency, progression and achievement of the desired level of education quality. Teachers are expected to understand and use these standards for lesson planning, instruction and assessment.

Content Standards

Content standards are evidence-based, rigorous and comparable regionally and globally. They have been formulated to target critical social, economic, political, cultural, environment, and employable skills gaps identified from a situational analysis. They were developed using examples and experiences from other countries and best practice, and contextualized to PNG contexts.

Content standards describe what (**content - knowledge, skills, values, and attitudes**) all students are expected to know and do (how well students must learn and apply what is set out in the content standards) at each grade-level before proceeding to the next grade. These standards are set at the national level and thus cannot be edited or changed by anyone except the National Subject-Based Standards Councils.

Content Standards;

- are evidenced-based,
- are rigorous and comparable to regional and global standards,
- are set at the national level,
- state or describe the expected levels of quality or achievement,
- are clear, measurable and attainable,
- are linked to and aligned with the ultimate aim and goals of SBE and SBC and overarching and SBC principles,
- delineate what matters, provide clear expectations of what students should progressively learn and achieve in school, and guide lesson planning, instruction, assessment,
- comprise knowledge, skills, values, and attitudes that are the basis for quality education,
- provide teachers a clear basis for planning, teaching, and assessing lessons and
- provide provinces, districts, and schools with a clear focus on how to develop and organise their instruction and assessment programs as well as the content that they will include in their curriculum.

Benchmarks

Benchmarks are derived from the content standards and benchmarked at the grade-level. Benchmarks are specific statements of what students should know (i.e., essential knowledge, skills, values or attitudes) at a specific grade-level or school level. They provide the basis for measuring students' attainment of a content standard as well as progress to the next grade of schooling.

Grade-level benchmarks;

- are evidenced-based,
- are rigorous and comparable to regional and global standards,
- are set at the grade level,
- are linked to the national content standards,
- are clear, measurable, observable and attainable,
- articulate grade level expectations of what students are able to demonstrate to indicate that they are making progress towards attaining the national content standards,
- provide teachers a clear basis for planning, teaching, and assessing lessons,
- state clearly what students should do with what they have learned at the end of each school-level,
- enable students' progress towards the attainment of national content standards to be measured, and
- enable PNG students' performance to be compared with the performance of students in other countries.

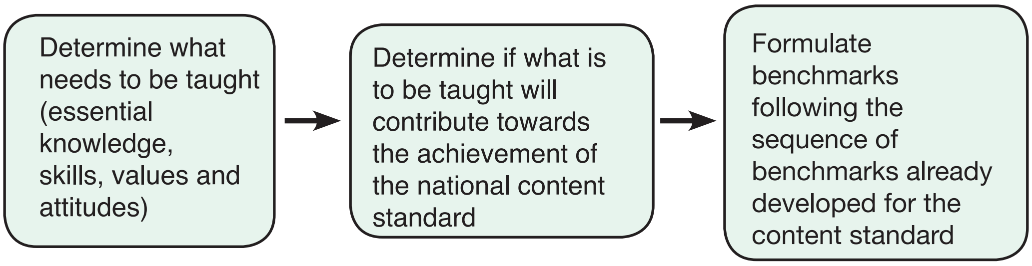
Approach for Setting National Content Standards and Grade-Level Benchmarks

Strands → Content Standards → Grade -Level Benchmark

Development of Additional Benchmarks

Teachers should develop additional benchmarks to meet the learning needs of their students. They should engage their students to learn about local, provincial, national and global issues that have not been catered for in the grade-level benchmarks but are important and can enhance students' understanding and application of the content. However, it is important to note that these benchmarks will not be nationally examined as they are not comparable. Only the benchmarks developed at the national level will be tested. This does not mean that teachers should not develop additional benchmarks. An innovative, reflect, creative and reflexive teacher will continuously reflect on his/her classroom practice and use evidence to provide challenging, relevant, and enjoyable learning opportunities for his/her students to build on the national expectations for students. Teachers should follow the following process when developing additional grade-level benchmarks.

Benchmark Development Process



Learning Objectives

Learning or instructional Objectives are precise statements of educational intent. They are formulated using a significant aspect or a topic derived from the benchmark, and is aligned with the educational goals, content standards, benchmarks, and performance standards. Learning objectives are stated in outcomes language that describes the products or behaviours that will be provided by students. They are stated in terms of measurable and observable student behaviour. For example, students will be able to identify all the layers of the earth.

Performance Standards

Performance Standards are concrete statements of how well students must learn what is set out in the content standards, often called the **“be able to do”** of “what students should know and be able to do.” Performance standards are the indicators of quality that specify how competent a students’ demonstration or performance must be. They are explicit definitions of what students **must do to demonstrate proficiency or competency at a specific level on the content standards**.

Performance standards;

- measure students’ performance and proficiency (using performance indicators) in the use of a specific knowledge, skill, value, or attitude in real life or related situations,
- provide the basis (performance indicators) for evaluating, reporting and monitoring students’ level of proficiency in use of a specific knowledge, skills, value, or attitude,
- are used to plan for individual instruction to help students not yet meeting expectations (desired level of mastery and proficiency) to make adequate progress towards the full attainment of benchmarks and content standards, and
- are used as the basis for measuring students’ progress towards meeting grade-level benchmarks and content standards.

Proficiency Standards

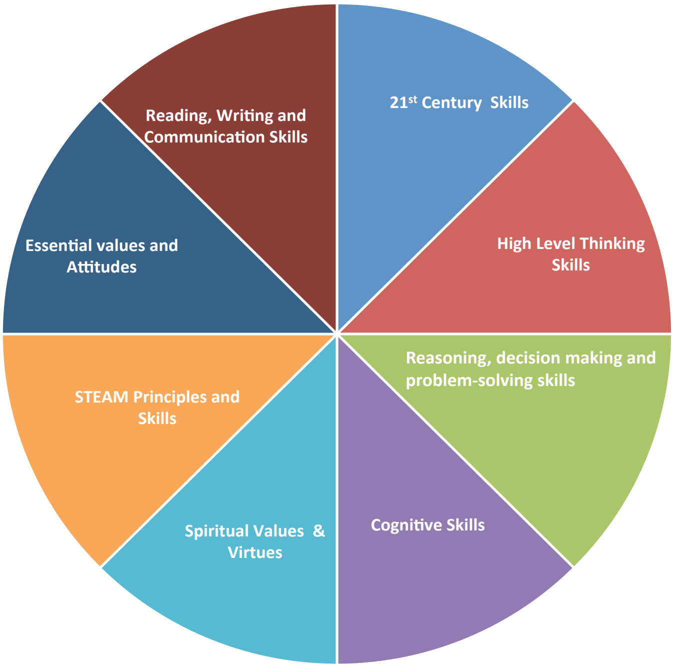
Proficiency standards describe what all students in a particular grade or school level can do at the end of a strand, or unit. These standards are sometimes called evidence outcomes because they indicate if students can actually apply or use what they have learnt in real life or similar situations. They are also categorized as benchmarks because that is what all students are expected to do before exiting a grade or are deemed ready for the next grade.

Core Curriculum

A core set of common learnings (knowledge, skills, values, and attitudes) are integrated into the content standards and grade-level benchmarks for all subjects. This is to equip all students with the most essential and in-demand knowledge, skills, and dispositions they will need to be successful in modern/postmodern work places, higher-education programs and to be productive, responsible, considerate, and harmonious citizens. Common set of learnings are spirally sequenced from Preparatory - Grade 12 to deepen the scope and increase the level of difficulty in the learning activities so that what is learned is reinforced at different grade levels.

The core curriculum includes:

- cognitive (thinking) skills (Refer to the syllabus for a list of these skills),
- reasoning, decision-making and problem-solving skills,
- high level thinking skills (analysis, synthesis and evaluation skills),
- 21st Century skills,
- reading, writing and communication skills,
- STEAM principles and skills,
- essential values and attitudes (personal and social values, and sustaining values), and
- spiritual values and virtues.



The essential knowledge, skills, values and attitudes comprising the core curriculum are interwoven and provide an essential and holistic framework for preparing all students for careers, higher education and citizenship.

All teachers are expected to include the core learnings in their lesson planning, teaching, and assessment of students in all their lessons. They are expected to foster, promote and model the essential values and attitudes as well as the spiritual values and virtues in their conduct, practice, appearance, and their relationships and in their professional and personal lives. In addition, teachers are expected to mentor, mould and shape each student to evolve and possess the qualities envisioned by society.

Core values and attitudes must not be taught in the classroom only; they must also be demonstrated by students in real life or related situations inside and outside of the classroom, at home, and in everyday life. Likewise, they must be promoted, fostered and modelled by the school community and its stakeholders, especially parents. A holistic approach to values and attitudes in teaching, promoting and modelling is critical to students and the whole school community to internalise the core values and attitudes and making them habitual in their work and school place, and in everyday life. Be it work values, relationship values, peace values, health values, personal and social values, or religious values, teachers should give equal prominence to all common learnings in their lesson planning, teaching, assessment, and learning interventions. Common learnings must be at the heart of all teaching and extra-curricular programs and activities.

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Science, Technology, Engineering, Arts and Mathematics

STEAM education is an integrated, multidisciplinary approach to learning that uses science, technology, engineering, arts and mathematics as the basis for inquiring about how STEAM has and continues to change and impact the social, political, economic, cultural and environmental contexts and identifying and solving authentic (real life) natural and physical environment problems by integrating STEAM-based principles, cognitive, high level and 21st Century skills and processes, and values and attitudes.

Geology is focused on both goals of STEAM rather than just the goal of problem-solving. This is to ensure that all students are provided opportunities to learn, integrate, and demonstrate proficiency on all essential STEAM principles, processes, skills, values and attitudes to prepare them for careers, higher education and citizenship.

Objectives

Students will be able to:

(i) Examine and use evidence to draw conclusions about how STEAM has and continues to change the social, political, economic, cultural and environmental contexts.
(ii) Investigate and draw conclusions on the impact of STEAM solutions to problems on the social, political, economic, cultural and environmental contexts.
(iii) Identify and solve problems using STEAM principles, skills, concepts, ideas and process.
(iv) Identify, analyse and select the best solution to address a problem.
(v) Build prototypes or models of solutions to problems.
(vi) Replicate a problem solution by building models and explaining how the problem was or could be solved.
(vii) Test and reflect on the best solution chosen to solve a problem.
(viii) Collaborate with others on a problem and provide a report on the process of problem solving used to solve the problem.
(ix) Use skills and processes learnt from lessons to work on and complete STEAM projects.
(x) Demonstrate STEAM principles, skills, processes, concepts and ideas through simulation and modelling.
(xi) Explain the significance of values and attitudes in problem-solving.

STEAM is a multidisciplinary and integrated approach to understanding how science, technology, engineering, arts and mathematics shape and are shaped by our material, intellectual, cultural, economic, social, political and environmental contexts. And for teaching students the essential in demand cognitive, high level and 21st Century skills, values and attitudes, and empower them to effectively use these skills and predispositions to identify and solve problems relating to the natural and physical environments as well as the impact of STEAM-based solutions on human existence and livelihoods, and on the social, political, economic, cultural, and environmental systems.

STEAM disciplines have and continue to shape the way we perceive knowledge and reality, think and act, our values, attitudes, and behaviours, and the way we relate to each other and the environment. Most of the things we enjoy and consume are developed using STEAM principles, skills, process, concepts and ideas. Things humans used and enjoyed in the past and at present are developed by scientists, technologists, engineers, artists and mathematicians to address particular human needs and wants. Overtime, more needs were identified and more products were developed to meet the ever changing and evolving human needs. What is produced and used is continuously reflected upon, evaluated, redesigned, and improved to make it more advanced, multipurpose, fit for purpose, and targeted towards not only improving the prevailing social, political, economic, cultural and environmental conditions but also to effectively respond to the evolving and changing dynamics of human needs and wants. And, at the same time, solutions to human problems and needs are being investigated and designed to address problems that are yet to be addressed and concurred. This is an evolving and ongoing problem-solving process that integrates cognitive, high level, and 21st Century skills, and appropriate values and attitudes.

STEAM is a significant framework and focal point for teaching and guiding students to learn, master and use a broad range of skills and processes required to meet the skills demands of PNG and the 21st Century. The skills that students will learn will reflect the demands that will be placed upon them in a complex, competitive, knowledge-based, information-age, technology-driven economy and society. These skills include cognitive (critical, synthetic, creative, reasoning, decision-making, and problem-solving) skills, high level (analysis, synthesis and evaluation) skills and 21st Century skills (see Appendix 4). Knowledge-based, information, and technology driven economies require knowledge workers not technicians. Knowledge workers are lifelong learners, are problem solvers, innovators, creators, critical and creative thinkers, reflective practitioners, researchers (knowledge producers rather than knowledge consumers), solutions seekers, outcomes oriented, evidence-based decision makers, and enablers of improved and better outcomes for all.

STEAM focuses on the skills and processes of problem solving. These skills and processes are at the heart of the STEAM movement and approach to not only problem solving and providing evidence-based solutions but also the development and use of other essential cognitive, high level and 21st Century skills. These skills are intertwined and used simultaneously to gain a broader understanding of the problems to enable creative, innovative, contextually relevant, and best solutions to be developed and implemented to solve the problems and attain the desired outcomes. It is assumed that by teaching students STEAM-based problem-solving skills and providing learning opportunities inside and outside the classroom will motivate more of them to pursue careers and academic programs in STEAM related fields thus, closing the skills gaps and providing a pool of cadre of workers required by technology, engineering, science, and mathematics-oriented industries.

STEAM Problem-Solving Processes

Problem-solving involves the use of problem-solving methods and processes to identify and define a problem, gather information to understand its causes, draw conclusions, and use the evidence to design and implement solutions to address it. Even though there are many different problem-solving methods and approaches, they share some of the steps of problem-solving, such as;

- identifying the problem,
- understanding the problem by collecting data,
- analyse and interpret the data,
- draw conclusions,
- use data to consider possible solutions,
- select the best solution,
- test the effectiveness of the solution by trialling and evaluating it, and
- review and improve the solution.

STEAM problem solving processes go from simple and technical to advance and knowledge-based processes. However, regardless of the type of process used, students should be provided opportunities to learn the essential principles and processes of problem solving and, more significantly, to design and create a product that addressed a real problem and meets a human need.

The following are some of the STEAM problem solving processes.

1. Engineering and Technology Problem Solving Methods and Approaches

Engineering and technology problem-solving methods are used to identify and solve problems relating to the physical world using the design process. The following are some of the methods and approaches used to solve engineering and technology related problems.

Parts Substitution

It is the most basic of the problem-solving methods. It simply requires the parts to be substituted until the problem is solved.

Diagnostics

After identifying a problem, the technician would run tests to pinpoint the fault. The test results would be used either as a guide for further testing or for replacement of a part, which also need to be tested. This process continues until the solution is found and the device is operating properly.

Troubleshooting

Troubleshooting is a form of problem solving, often applied to repair failed products or processes.

Reverse Engineering

Reverse engineering is the process of discovering the technological principles underlying the design of a device by taking the device apart, or carefully tracing its workings or its circuitry. It is useful when students are attempting to build something for which they have no formal drawings or schematics.

Divide and Conquer

Divide and conquer is the technique of breaking down a problem into sub-problems, then breaking the sub-problems down even further until each of them is simple enough to be solved. Divide and conquer may be applied to all groups of students to tackle sub-problems of a larger problem, or when a problem is so large that its solution cannot be visualised without breaking it down into smaller components.

Extreme Cases

Considering “extreme cases” – envisioning the problem in a greatly exaggerated or greatly simplified form, or testing using extreme condition – can often help to pinpoint a problem. An example of the extreme-case method is purposely inputting an extremely high number to test a computer program.

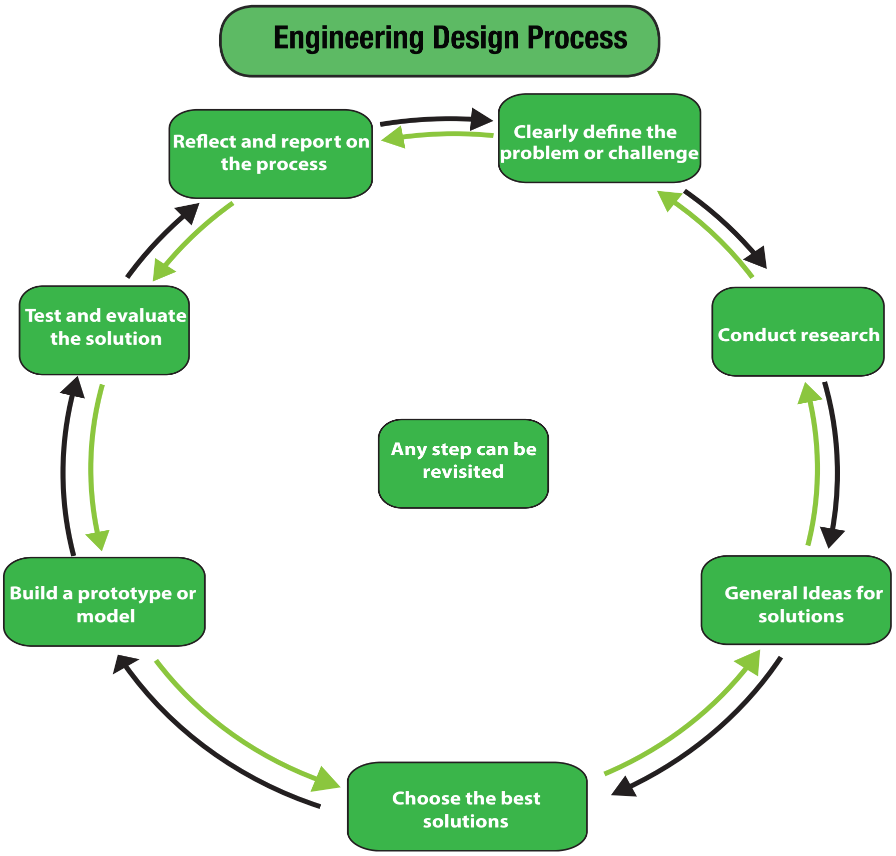
Trial and Error

The trial and error method involve trying different approaches until a solution is found. It is often used as a last resort when other methods have been exhausted.

2. Engineering Design Process

Technological fields use the engineering design process to identify and define the problem or challenge, investigate the problem, collect and analyse data, and use the data to formulate potential solutions to the problem, analyse each of the solutions in terms of its strengths and weaknesses, and choose the best solution to solve the problem. It is an open-ended problem-solving process that involves the full planning and development of products or services to meet identified needs. It involves a sequence of steps such as the following:

1. Analyse the context and background, and clearly define the problem.
2. Conduct research to determine design criteria, financial or other constraints, and availability of materials.
3. Generate ideas for potential solutions, using processes such as brainstorming and sketching.
4. Choose the best solution.
5. Build a prototype or model.
6. Test and evaluate the solution.
7. Repeat steps as necessary to modify the design or correct faults.
8. Reflect and report on the process.



STEAM-Based Lesson planning

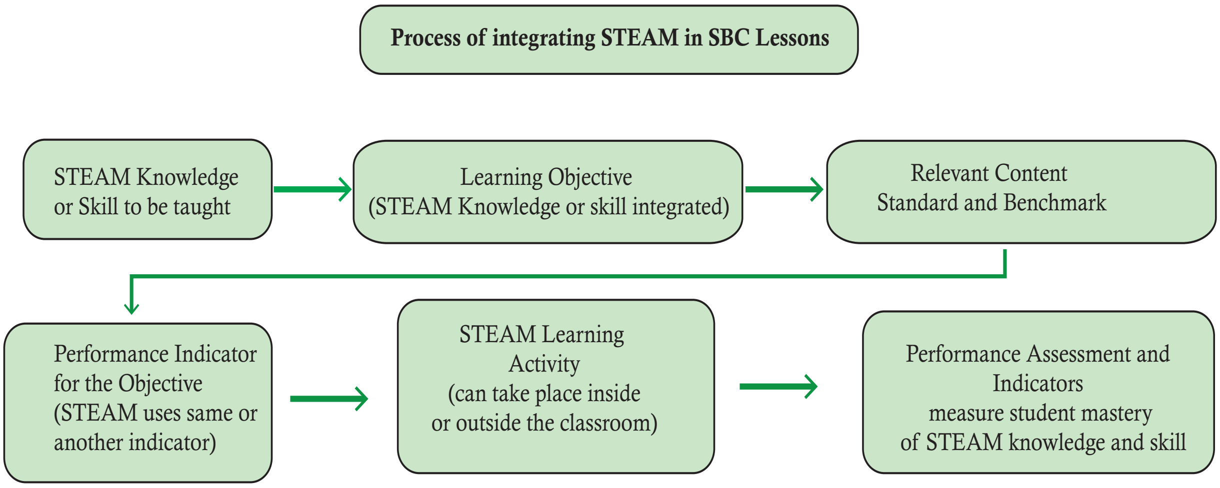
Effective STEAM lesson planning is key to the achievement of expected STEAM outcomes. STEAM skills can be planed and taught using separate STEAM-based lesson plans or integrated into the standards-based lesson plans. To effectively do this, teachers should know how to write effective standards and STEAM-based lesson plans.

An example of a STEAM-based lesson plan is provided in the Appendix. Teachers should use this to guide them to integrate STEAM content and teaching, learning and assessment strategies into their standards-based lesson plans.

Knowing how to integrate STEAM problem-solving skills, principles, values and attitudes as well as STEAM teaching, learning, and assessment strategies into standards-based lesson plans is essential for achieving the desired STEAM learning outcomes. When integrating STEAM problem-solving skills into the standards-based lesson plans, teachers should ensure that these skills are not only effectively aligned to the learning objective and performance standards, they must also be effectively taught and assessed.

Teachers are expected to integrate the essential STEAM principles, processes, skills, values and attitudes described in the grade 12 benchmarks when formulating their standards-based lesson plans. Opportunities should be provided inside and outside of the classroom for students to learn, explore, model and apply what they learn in real life or related situations. These learning experiences will enable students to develop a deeper understanding of STEAM principles, processes, skills, values and attitudes and appreciate their application in real life to solve problems.

Process for Integrating STEAM Principles and Problem-Solving Skills into Standards-Based Lessons



Teachers should follow the steps given below when integrating STEAM problem-solving principles and skills into their standards-based lesson plans.

Step 1: Identify the STEAM knowledge or skill to be taught (From the table of KSVAs for each content standard and benchmark). This could already be captured in the learning objective stated in the standards-based lesson plan.

Step 2: Develop and include a performance standard or indicator for measuring student mastery of the STEAM knowledge or skill *(e.g.* level of acceptable competency or proficiency) if this is different from the one already stated in the lesson plan.

Step 3: Develop student learning activity (An activity that will provide students the opportunity to apply the STEAM knowledge or skill specified by the learning objective and appropriate statement of the standards). Activity can take place inside or outside of the classroom, and during or after school hours.

Step 4: Develop and use performance descriptors (standards or indicators) to analyse students' STEAM related behaviours and products (results or outcomes), which provide evidence that the student has acquired and mastered the knowledge or skill of the learning objective specified by the indicator (s) of the standard (s).

STEAM Teaching Strategies

STEAM education takes place in both formal and informal classroom settings. It takes place during and after school hours. It is a continuous process of inquiry, data analysis, making decisions about interventions, and implementing and monitoring interventions for improvements.

There are a variety of STEAM teaching strategies. However, teaching strategies selected must enable teachers to guide students to use the engineering and artistic design processes to identify and solve natural and physical environment problems by designing prototypes and testing and refining them to effectively mitigate the problems identified. The following are some of the strategies that could be used to utilise the STEAM approach to solve problems and coming up with technological solutions.

- *Inquiry-Based Learning*
- *Problem-Based Learning*
- *Project-based learning,*
- *Collaborative Learning*

Collaborative learning involves individuals from different STEAM disciplines and expertise in a variety of STEAM problem solving approaches working together and sharing their expertise and experiences to inquire into and solve a problem.

Teachers should plan to provide students opportunities to work in collaboration and partnership with experts and practitioners engaged in STEAM related careers or disciplines to learn first-hand about how STEAM related skills, processes, concepts, and ideas are applied in real life to solve problems created by natural and physical environments. Collaborative learning experiences can be provided after school or during school holidays to enable students to work with STEAM experts and practitioners to inquiry and solve problems by developing creative, innovative and sustainable solutions. Providing real life experiences and lessons, e.g., by involving students to actually solve a scientific, technological, engineering, or mathematical, or Arts problem, would probably spark their interest in a STEAM career path. Developing STEAM partnerships with external stakeholders e.g., high education institutions, private sector, research and development institutions, and volunteer and community development organizations can enhance students' learning and application of STEAM problem solving principles and skills.

Some examples of STEAM-related partnership experiences may include:

- *Participatory Learning*
- *Group-Based Learning*
- *Task Oriented Learning*
- *Action Learning*
- *Experiential Learning*
- *Modelling*
- *Simulation*

STEAM Learning Strategies

Teachers should include in their lesson plans STEAM learning activities. These activities should be aligned to principle or a skill planned for students to learn and demonstrate proficiency at the end of the lesson to expose students to STEAM and giving them opportunities to explore STEAM-related concepts, they will develop a passion for it and, hopefully, pursue a job in a STEAM field. Providing real life experiences and lessons, e.g., by involving students to actually solve a scientific, technological, engineering, or mathematical, or arts problem, would probably spark their interest in a STEAM career path. This is the theory behind STEAM education.

STEAM-Based Assessment

STEAM-based assessment is closely linked to standards-based assessment where assessment is used to assess students' level of competency or proficiency of a specific knowledge, skill, value, or attitude taught using a set of performance standards (indicators or descriptors). The link also includes the main components such as the purpose, the assessment principles and assessment strategies and tools.

In STEAM-based assessment, assessments are designed for what students should know and be able to do. In STEAM learning, students are assessed in a variety of ways including portfolios, project/problem-based assessments, backwards design, authentic assessments, or other student-centered approaches.
When planning and designing the assessment, teachers should consider the authenticity of the assessment by designing an assessment that relates to a real world task or discipline specific attributes such as simulation, role play, placement assessment, live projects and debates. These tasks should make the activity meaningful to the student, and therefore be motivating as well as developing employability skills and discipline specific attributes.

Effective STEAM-Based Assessment Strategies

The following are the six assessment tools and strategies shown to impact teaching and learning as well as help teachers foster a 21st Century learning environment in their classrooms.

1. *Rubrics*
2. *Performance-Based Assessments (PBAs)*
3. *Portfolios*
4. *Student self-assessment*
5. *Peer-assessment*
6. *Student Response Systems(SRS).*

Although the list does not include all innovative assessment strategies, it includes what we think are the most common strategies, and ones that may be particularly relevant to the educational context of developing countries in this 21st Century. Many of the assessment strategies currently in use fit under one or more of the categories discussed. Furthermore, it is important to note that these strategies also connect in a variety of ways.

1. Rubrics

Rubrics are both a tool to measure students' knowledge and ability as well as an assessment strategy. A rubric allows teachers to measure certain skills and abilities not measurable by standardized testing systems that assess discrete knowledge at a fixed moment in time. Rubrics are also frequently used as part of other assessment strategies including; portfolios, performances, projects, peer-review and self-assessment which are also elaborated in this section.

2. Performance-Based Assessments

Performance-Based Assessments (PBA), also known as project-based or authentic assessments, are generally used as a summative evaluation strategy to capture not only what students know about a topic, but if they have the skills to apply that knowledge in a "real-world" situation. By asking them to create an end product. PBA pushes students to synthesize their knowledge and apply their skills to a potentially unfamiliar set of circumstances that is likely to occur beyond the confines of a controlled classroom setting.

The implementation of performance-based assessment strategies can also impact other instructional strategies in the classroom.

3. Portfolio Assessment

Portfolios are a collection of student work gathered over time that is primarily used as a summative evaluation method. The most salient characteristic of the portfolio assessment is that rather than being a snapshot of a student's knowledge at one point in time (like a single standardized test), it highlights student effort, development, and achievement over a period of time; portfolios measure a student's ability to apply knowledge rather than simply regurgitate. They are considered both student-centred and authentic assessments of learning.

4. Self-assessment

While the previous assessment tools and strategies listed in this report generally function as summative approaches, self-assessment is generally viewed as a formative strategy, rather than one used to determine a student's final grade. Its main purpose is for students to identify their own strengths and weakness and to work to make improvements to meet specific criteria. Self-assessment occurs when students judge their own work to improve performance as they identify discrepancies between current and desired performance". In this way, self-assessment aligns well with standards-based education because it provides clear targets and specific criteria against which students or teachers can measure learning.

Self-assessment is used to promote self-regulation, to help students reflect on their progress and to inform revisions and improvements on a project or paper. In order for self-assessment to be truly effective four conditions must be in place: the self-assessment criteria is negotiated between teachers and students, students are taught how to apply the criteria, students receive feedback on their self-assessments and teachers help students use assessment data to develop an action plan.

5. Peer assessment

Peer assessment, much like self-assessment, is a formative assessment strategy that gives students a key role in evaluating learning. Peer assessment approaches can vary greatly but, essentially, it is a process for learners to consider and give feedback to other learners about the quality or value of their work. Peer assessments can be used for variety of products like papers, presentations, projects, or other skilled behaviours. Peer assessment is understood as more than only a grading procedure and is also envisioned as teaching strategy since engaging in the process develops both the assessor and assessee's skills and knowledge.

Curriculum Integration

What is Curriculum Integration?

Curriculum integration is making connections in learning across the curriculum. The ultimate aim of curriculum integration is to act as a bridge to increase students' achievement and engage in relevant curriculum. (Susan M. Drake and Rebecca C. Burns)

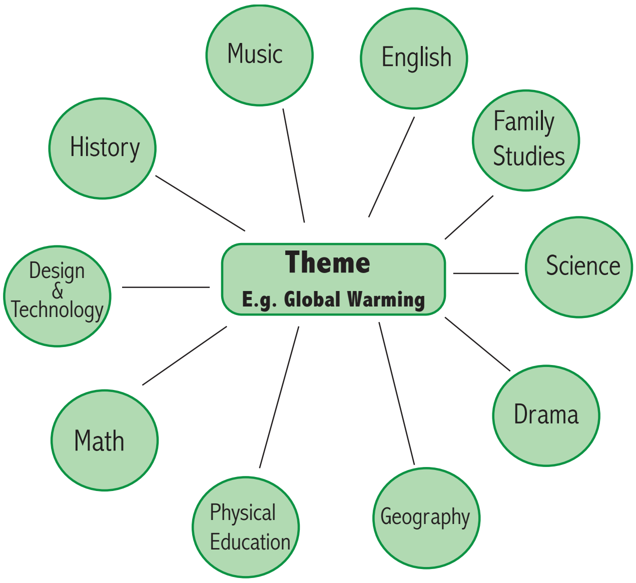
Teachers must develop intriguing curriculum by going beyond the traditional teaching of content based or fragmented teaching to one who is knowledge based and who should be perceived as a 21st Century innovative educator. Curriculum integration is a holistic approach to learning thus curriculum integration in PNG SBC will have to equip students with the essential knowledge, skills, values and attitudes that are deemed 21st Century.

There are three approaches that PNG SBC will engage to foster conducive learning for all its children whereby they all can demonstrate proficiency at any point of exit. Adapting these approaches will have an immense impact on the lives of these children thus they can be able to see themselves as catalyst of change for a competitive PNG. Not only that but they will be comparable to the world standards and as global citizens.

Engaging these three approaches in our curriculum will surely sharpen the knowledge and ability of each child who will foresee themselves as assets through their achievements thus contribute meaningfully to their country. They themselves are the agents of change. Integrated learning will bear forth a generation of knowledge based populace who can solve problems and make proper decisions based on evidence. Thus, PNG can achieve its goals like the Medium Term Development Goals (MTDG) and aims such as the Vision 2050 for a happy, healthy and wealthy society whereby, all its citizens should have access and fair distribution to income, shelter, health, education and general good and services improving the general standard of living for PNG in the long run.

1. (i) Multidisciplinary Approach

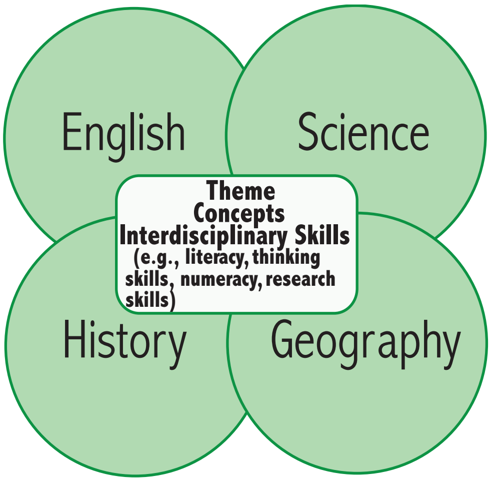
In this approach learning involves a theme or concept that will be taught right across all subject area of study by students. That is, content of a particular theme will be taught right across all subjects as shown in the diagram below. For instance, if the theme is global warming, subject areas create lessons or assessment as per their subjects around this theme. Social Science will address this issue, Science and all other subject likewise.



1. (ii) Interdisciplinary Approach

This approach addresses learning similarly to the multidisciplinary approach of integrated learning whereby learning takes place within the subject area. However, it is termed interdisciplinary in that the core curriculum of learning is interwoven into each subject under study by the students. For instance; in Social Science under the strand of geography students write essay on internal migration however, apart from addressing the issues of this topic, they are to apply the skill of writing text types in their essay such as argumentative essay, informative, explanatory, descriptive, expository and narrative essay while writing their essay. They must be able to capture the mechanics of English skills such as grammar, punctuation and so forth. Though these skills are studied under English they are considered as core skills that cut across all subjects under study. For example; if Science students were to write about human development in biology then the application of writing skills has to be captured by the students in their writing. It is not seen as an English skill but a standard essential skill all students must know and do regardless.

Therefore, essential knowledge, skills, values and attitudes comprising the core curriculum are interwoven and provide an essential and holistic framework for preparing all students for careers, higher education and citizenship in this learning.



2. Intradisciplinary approach

This approach involves teachers integrate sub disciplines within a subject area. For instance, within the subject Social Science, the strands (disciplines) of geography, environment, history, political science and environment will all be captured studying a particular content for Social Science. For example, under global warming, students will study the geographical aspects of global warming, environmental aspect of global warming and likewise for history, political science and economics. Thus, children are well aware of the issues surrounding global warming and can address it confidently at each level of learning.

3. Trans disciplinary Approach

In this approach learning goes beyond the subject area of study. Learning is organized around students' questions and concerns. That is, where there is a need for change to improve lives, students develop their own curriculum to effect these need. The trans-disciplinary approach addresses real-life situations thus giving the opportunity to students to attain real life skills. This learning approach is more to do with Project–Based Learning also referred to as problem-based learning or place- based learning.

Below are the three steps to planning project based curriculum.

1. Teachers and students select a topic of study based on student interests, curriculum standards, and local resources.
2. The teacher finds out what the students already know and helps them generate questions to explore. The teacher also provides resources for students and opportunities to work in the field
3. Students share their work with others in a culminating activity. Students display the results of their exploration and review and evaluate the project.

For instance; students may come up with slogans for school programs such as 'Our culture – clean city for a healthier PNG'. The main aim could be to curb betel nut chewing in public areas especially around bus stops and local markets. Here, students draw up their own instructions and criteria for assessment which is; they have to clean the nearest bus stop or local market once a week throughout the year. They also design and create posters to educate the general public as their program continues. They can also involve the town council and media to assist them especially to carry out awareness.

Studies have proven that Project based-programs have led to the following:

- Students go far beyond the minimum effort
- Make connections among different subject areas to answer open-ended questions
- Retain what they have learnt
- Apply learning to real-life problems
- Have fewer discipline problems
- Lower absenteeism

SUBJECT AREAS

Theme
Concepts
Life Skills

Real world Context -
(Voluntary services/Part time
job experience, exchange programs)

Students Questions

These integrated learning approaches will demand for teaches to be proactive in order to improve students learning and achievements. In order for PNG Standards-Based Curriculum to serve its purpose fully, these three approaches must be engaged for better learning for the children of Papua New Guinea now and in the future.

Essential Knowledge, Skills, Values and Attitudes and Scientific Thinking Process

Students' level of proficiency and progression towards the attainment of content standards will depend on their mastery and application of essential knowledge, skills, values, and attitudes in real life or related situations. Provided here are examples of different types of knowledge, processes, skills, values, and attitudes that all students are expected to learn and master as they progress through the grades. These are expanded and deepen in scope and the level of difficulty and complexity are increased to enable students to study in-depth the subject content as they progress from one grade to the next.

These knowledge, skills, values and attitudes have been integrated into the content standards and benchmarks. They will also be integrated into the performance standards. Teachers are expected to plan and teach essential knowledge, skills, values and attitudes in their lessons, and assess students' performance and proficiency, and progression towards the attainment of content standards.

Types of Knowledge

There are different types of knowledge. These include;

- Public and private (privileged) knowledge
- Specialised knowledge
- Good and bad knowledge
- Concepts, processes, ideas, skills, values, attitudes
- Theory and practice
- Fiction and non-fiction
- Traditional, modern, and postmodern knowledge

- Subject and discipline-based knowledge
- Lived experiences
- Evidence and assumptions
- Ethics and Morales
- Belief systems
- Facts and opinions
- Wisdom
- Research evidence and findings
- Solutions to problems

Types of Processes

There are different types of processes. These include;

- Problem-solving
- Logical reasoning
- Decision-making
- Reflection

- Cyclic processes
- Mapping (e.g. concept mapping)
- Modelling
- Simulating

Science Inquiry processes include:

- Gathering information
- Analysing information
- Evaluating information
- Making judgements
- Taking actions

Types of Skills

There are different types of skills. These include:

1. Cognitive (Thinking) Skills

Thinking skills can be categorized into **critical thinking** and **creative thinking** skills.

i. Critical Thinking Skills

A person who thinks critically always evaluates an idea in a systematic manner before accepting or rejecting it. Critical thinking skills include;

- Attributing
- Comparing and contrasting
- Grouping and classifying
- Sequencing
- Prioritising
- Analysing
- Detecting bias
- Evaluating
- Metacognition (Thinking about thinking)
- Making informed conclusions.

ii Creative Thinking Skills

A person who thinks creatively has a high level of imagination, able to generate original and innovative ideas, and able to modify ideas and products. Creative thinking skills include;

- Generating ideas
- Deconstruction and reconstruction
- Relating
- Making inferences
- Predicting
- Making generalisations
- Visualizing
- Synthesising
- Making hypothesis
- Making analogies
- Invention
- Transformation
- Modeling
- Simulating

2. **Reasoning Skills** - Reason is a skill used in making a logical, just, and rational judgment.

3. **Decision-Making Skills** - Decision-making involves selection of the best solution from various alternatives based on specific criteria and evidence to achieve a specific aim.

4. **Problem Solving Skills –** These skills involve finding solutions to challenges or unfamiliar situations or unanticipated difficulties in a systematic manner.

5. Literacy Skills

A strong emphasis must be placed on various types of literacy, from financial to technological, from media to mathematical, from content to cultural. Literacy may be defined as the ability of an individual to use information to function in society, to achieve goals and to develop her or his knowledge and potential. Teachers emphasize certain aspects of literacy over others, depending on the nature of the content and skills they want students to learn.

The following literacy skills are intended to be exemplary rather than definitive	
• Listens, read, write, and speak with comprehension and clarity • Define and apply discipline-based conceptual vocabulary • Describe people, places, and events, and the connections between and among them • Arrange events in chronological sequence • Differentiate fact from opinion • Determine an author's purpose • Determine and analyse similarities and differences • Analyse cause and effect relationships • Explore complex patterns, interactions and relationships • Differentiate between and among various options	• Listens, read, write, and speak with comprehension and clarity • Define and apply discipline-based conceptual vocabulary • Describe people, places, and events, and the connections between and among them • Arrange events in chronological sequence • Differentiate fact from opinion • Determine an author's purpose • Determine and analyse similarities and differences • Analyse cause and effect relationships • Develop an ability to use and apply abstract principals • Explore and/or observe, identify, and analyse how individuals and/or societies relate to one another

6. **High Level Thinking Skills -** These skills include analysis, synthesis, and evaluation skills.

i Analysis Skills – Analysis skills involve examining in detail and breaking information into parts by identifying motives or causes, underlying assumptions, hidden messages; making inferences and finding evidence to support generalisations, claims, and conclusions.

Key Words				
Analyse	Differences	Find	List	Similar to
Appraise	Discover	Focus	Motivate	Simplify
Arrange	Discriminate	Function	Omit	Take part in
Assumption	Discussion	Group	Order	Test for
Breakdown	Distinction	Highlight	Organize	Theme
Categorize	Distinguish	In-depth	Point out	
Cause & effect	Dissect	Inference	Research	
Choose	Divide	Inspect	See	
Classify	Establish	Isolate	Select	
Comparing	Examine	Investigate	Separate	

Synthesis Skills – Synthesis skills involve changing or creating something new, compiling information together in a different way by combining elements in a new pattern proposing alternative solutions.
Evaluation Skills – Evaluation skills involve justifying and presenting and defending opinions by making judgments about information, validity of ideas or quality of work based on set criteria.

Types of Values

Personal engagement and civic engagement strategies help young people to acquire and apply skills and dispositions that will prepare them to become competent and responsible citizens.

1. Personal Values (importance, worth, usefulness, etc.)

Core values	Sustaining values
• Sanctity of life • Truth • Aesthetics • Honesty • Human • Dignity • Rationality • Creativity • Courage • Liberty • Affectivity • Individuality	• Self-esteem • Self-reflection • Self-discipline • Self-cultivation • Principal morality • Self-determination • Openness • Independence • Simplicity • Integrity • Enterprise • Sensitivity • Modesty • Perseverance

2. Social Values

Core values	Sustaining values
• Sanctity of life • Truth • Aesthetics • Honesty • Human • Dignity • Rationality • Creativity • Courage • Liberty • Affectivity • Individuality	• Self-esteem • Self-reflection • Self-discipline • Self-cultivation • Principal morality • Self-determination • Openness • Independence • Simplicity • Integrity • Enterprise • Sensitivity • Modesty • Perseverance

Types of Attitudes

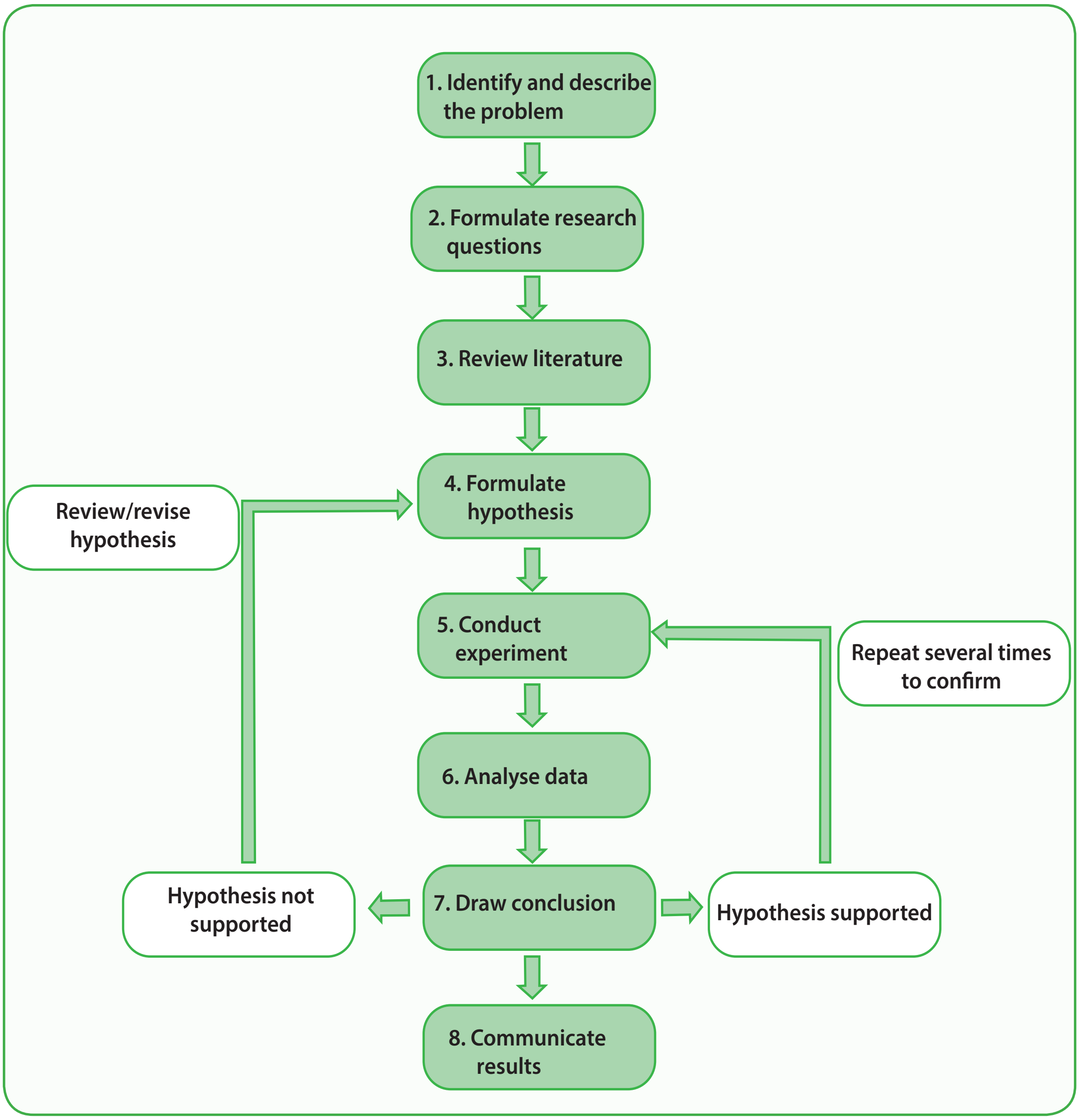
Attitudes - Ways of thinking and behaving, points of view	
• Optimistic • Participatory • Critical • Creative • Appreciative • Empathetic • Caring and concern • Positive • Confident • Cooperative	• Responsible • Adaptable to change • Open-minded • Diligent • With a desire to learn • With respect for self, life, equality and excellence, evidence, fair play, rule of law, different ways of life, beliefs and opinions, and the environment.

Scientific Thinking Process

Scientists engage in scientific inquiry by following key science practices that enable them to understand the natural and physical world and answer questions about it. Science students must become proficient at these practices to develop an understanding of how the scientific enterprise is conducted. These practices include skills from daily life and school studies that students use in a systemic way to conduct scientific inquiry. There are six (6) basic science process skills science students have to master before they apply the science inquiry problem-solving approach. The process skills that are at the heart of the scientific inquiry and problem-solving process are:

- Observation
- Communication
- Classification
- Measurement
- Inference
- Prediction

The science practices are fundamental to all science disciplines. The eight (8) steps that are fundamental to scientific inquiry are outlined below. The steps in the process vary, depending on the purpose of the inquiry and the type of questions or hypothesis created.



The steps above should be taught and demonstrated by students separately and jointly before they implement the inquiry process. Students should be guided through every step of the process so that they can explain them, their importance and use the steps and the whole process proficiently to identify, investigate and solve problems. A brief explanations and examples of each step are provided below to assist teachers plan and teach each step. Students should be provided with opportunities to practice and reflect on each step until they demonstrate the expected level of proficiency before moving on to the next step.

Step 1: Identify and describe the problem

Problems are identified mainly from observations and the use the five senses – smell, sight, sound, touch and taste. Students should be guided and provided opportunities to identify natural and physical environment problems using their five senses and describe what the problem is and its likely causes.

Example: *Observation*

- When I turn on a flashlight using the on/off switch, light comes out of one end.

Step 2: Formulate research question

After the problem is identified and described, the question to be answered is then formulated. This question will guide the scientist in conducting research and experiments.

Example: *Question*

- What makes light comes out of a flash light when I turn it on?

Step 3: Review literature

It is more likely that the research problem and question have already been investigated and reported by someone. Therefore, after asking the question, the scientist spends some time reading and reviewing papers and books on past research and discussions to learn more about the problem and the question ask to prepare her for his own research. Conducting literature review helps the scientist to better understand his/her research problem, refine the research question and decide on experiment/research approach before the experiment is conducted.

Example: *Literature review*

- The scientist may look in the flashlight's instruction manual for tips or conduct online search on how flashlights work using the manufacturer's or relevant websites. Scientist may even analyse information and past experiments or discoveries regarding the relationship between energy and light.

Step 4: Formulate hypothesis

With a question in mind, the researcher decides on what he/she wants to test (The question may have changed as a result of the literature review).
The research will clearly state what he/she wants to find out by carrying out the experiment. He/She will make an educated guess that could answer the question or explain the problem. This statement is called a hypothesis. A hypothesis guides the experiment and must be testable.

Example: *Hypothesis*

- The batteries inside a flashlight give it energy to produce light when the flashlight is turned on.

Step 5: Conduct experiment

This step involves the design and conduct of experiment to test the hypothesis. Remember, a hypothesis is only an educated guess (a possible explanation), so it cannot be considered valid until an experiment verifies that it is valid.

Example: *Experimental Procedure*

- Remove the batteries from the flashlight, and try to turn it on using the on/off switch.
  Result: The flashlight does not produce light
- Reinsert the batteries into the flashlight, and try to turn it on using the on/off switch.
  Result: The flashlight does produce light.
- Write down these results

In general, it is important to design an experiment to measure only one thing at a time. This way, the researcher knows that his/her results are directly related to the one thing he/she changed. If the experiment is not designed carefully, results may be confusing and will not tell the researcher anything about his/her hypothesis.

Researchers collect data while carrying out their experiments. Data are pieces of information collected before, during, or after an experiment. To collect data, researchers read the measuring instruments carefully. Researchers record their data in notebooks, journals, or on a computer.

Step 6: Analyse data

Once the experiment is completed, the data is then analysed to determine the results. In addition, performing the experiment multiple times can be helpful in determining the credibility of the data.

Example: *Analysis*

- Record the results of the experiment in a table.
- Review the results that have been written down.

Step 7: Draw conclusions

If the hypothesis was testable and the experiment provided clear data, scientist can make a statement telling whether or not the hypothesis was correct. This statement is known as a conclusion. Conclusions must always be backed up by data. Therefore, scientists rely heavily on data so they can make an accurate conclusion.

If the data support the hypothesis, then the hypothesis is considered correct or valid.

If the data do not support the hypothesis, the hypothesis is considered incorrect or invalid. From here, if the hypothesis is invalid, the scientist can modify it and revert back to step 4.

Example: *Valid Hypothesis*

- The flashlight did not produce light without batteries. The flashlight did produce light when batteries were inserted.

Therefore, the hypothesis that batteries give the flashlight energy to produce light is valid, given that no changes are made to the flashlight during the experiment.

Example: *Invalid Hypothesis*

- The flashlight did NOT produce light when the batteries were inserted. Therefore, the hypothesis that batteries give the flashlight energy to produce light is invalid.

In this case, the hypothesis would have to be modified to say something like, "The batteries inside a flashlight give it energy to produce light when the batteries are in the correct order and when the flashlight is turned on." Then, another experiment would be conducted to test the new hypothesis.
An invalid hypothesis is not a bad thing! Scientists learn something from both valid and invalid hypotheses. If a hypothesis is invalid, it must be rejected or modified. This gives scientists an opportunity to look at the initial observation in a new way. They may start over with a new hypothesis and conduct a new experiment. Doing so is simply the process of scientific inquiry and learning.

Step 8: Communicate findings

Scientists generally tell others what they have learned. Communication is a very important component of scientific progress and problem solving. It gives other people a chance to learn more and improve their own thinking and experiments. Many scientists' greatest breakthroughs would not have been possible without published communication or results from previous experimentation.

Every experiment yields new findings and conclusions. By documenting both the successes and failures of scientific inquiry in journals, speeches, or other documents, scientists are contributing information that will serve as a basis for future research and for solving problems relating to both the natural and physical worlds. Therefore, communication of investigative findings is an important step in future scientific discovery and in solving social, political, economic, cultural, and environmental problems.

Example: *Communication of findings*

- Write your findings in a report or an article and share it with others, or present your findings to a group of people. Your work may guide someone else's research on creating alternative energy sources to generate light, additional uses for battery power, etc.

Teaching and Learning Strategies

Scientific teaching emphasises and embraces the use of cognitive, reasoning, decision-making, problem solving and higher level thinking skills to teach to enhance students' understanding of inter-disciplinary concepts and issues in relation to environment, geography, history, politics and economic within PNG and globally. It aims to provide a meaningful pedagogical framework for teaching and learning essential and in demand knowledge, skills, values, and attitudes that are required for the preparation of students for careers, higher education and citizenship in the 21st Century.

Students must be prepared to gather and understand information, analyse issues critically, learn independently or collaboratively, organize and communicate information, draw and justify conclusions, create new knowledge, and act ethically.

These teaching and learning strategies will help teachers to;

- familiarize themselves with different methods of teaching in the classroom
- develop an understanding of the role of a teacher for application of various methods in the classroom

Successful teachers always keep in view that teaching must "be dynamic, challenging and in accordance with the learner's comprehension. He/she does not depend on any single method for making his/her teaching interesting, inspirational and effective".

A detailed table of Teaching and Learning Strategies are outlined below:

STRATEGY	TEACHER	STUDENTS
CASE STUDY Used to extend students' understanding of real life issues	Provide students with case studies related to the topic of the lesson and allow them to analyse and evaluate.	Study the case study and identify the problem addressed. They analyse the problem and suggest solutions supported by conceptual justifications and make presentations. This enriches the students' existing knowledge of the topic.
DEBATE A method used to increase students' interest, involvement and participation	Provide the topic or question of debate on current issues affecting a bigger population, clearly outlining the expectations of the debate. Explain the steps involved in debating and set a criteria/ standard to be achieved.	Conduct researches to gather supporting evidence about the selected topic and summarising the points. They are engaged in collaborative learning by delegating and sharing tasks to group members. When debating, they improve their communication skills.

DISCUSSION The purpose of discussion is to educate students about the process of group thinking and collective decision.	The teacher opens a discussion on certain topic by asking essential questions. During the discussion, the teacher reinforces and emphasises on important points from students responses. Teacher guide the direction to motivate students to explore the topic in greater depth and the topic in more detail. Use how and why follow-up questions to guide the discussion toward the objective of helping students understand the subject and summarise main ideas.	Students ponder over the question and answer by providing ideas, experiences and examples. Students participate in the discussion by exchanging ideas with others.
GAMES AND SIMULATIONS **Encourages motivation and creates a spirit of competition and challenge to enhance learning**	Being creative and select appropriate games for the topic of the lesson. Give clear instructions and guidelines. The game selected must be fun and build a competitive spirit to score more than their peers to win small prices.	Go into groups and organize. Follow the instructions and play to win
OBSERVATION Method used to allow students to work independently to discover why and how things happen as the way they are. It builds curiosity.	Give instructions and monitor every activity students do	Students possess instinct of curiosity and are curious to see the things for themselves and particularly those things which exist around them. A thing observed and a fact discovered by the child for himself becomes a part of mental life of the child. It is certainly more valuable to him than the same fact or facts learnt from the teacher or a book. Students Observe and ask essential questions Record Interpret
PEER TEACHING & LEARNING (power point presentations, pair learning) Students teach each other using different ways to learn from each other. It encourages; team work, develops confidence, feel free to ask questions, improves communication skills and most importantly develop the spirit of inquiry.	Distribute topics to groups to research and teach others in the classroom. Go through the basics of how to present their peer teaching.	Go into their established working groups. Develop a plan for the topic. Each group member is allocated a task to work on. Research and collect information about the topic allocated to the group. Outline the important points from the research and present their findings in class.

PERFORMANCE-RELATED TASKS (dramatization, song/ lyrics, wall magazines) Encourages creativity and take on the overarching ideas of the topic and are able to recall them at a later date	Students are given the opportunity to perform the using the main ideas of a topic. Provide the guidelines, expectations and the set criteria	Go into their established working groups. Being creative and create dramas, songs/lyrics or wall magazines in line with the topic.
PROJECT (individual/group) Helps students complete tasks individually or collectively	Teacher outline the steps and procedures of how to do and the criteria	Students are involved in investigations and finding solutions to problems to real life experiences. They carry out researches to analyse the causes and effects of problems to provide achievable solutions. Students carefully utilise the problem-solving approach to complete projects.
USE MEDIA & TECHNOLOGY to teach and generate engagement depending on the age of the students	Show a full movie, an animated one, a few episodes form documentaries, you tube movies and others depending on the lesson. Provide questions for students to answer before viewing	Viewing can provoke questions, debates, critical thinking, emotion and reaction. After viewing, students engage in critical thinking and debate

Strands, Units and Topics

This section of the teacher guide contains the Geology content to be taught in grade 12. It consists of;

- a brief explanation of how the topics, learning objectives and lesson topics are derived.
- an overview of the content distributed according to the four terms in an academic year;
- the unit of work per strand

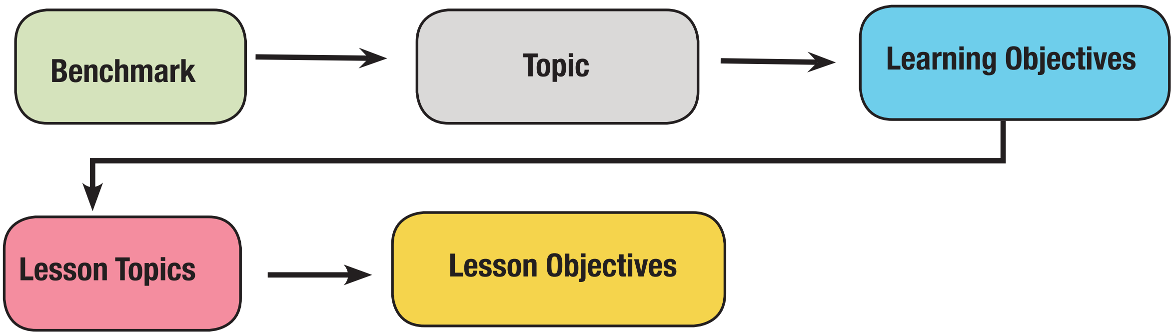
Geology is organized around two main strands – Science as Inquiry and Earth Science. These strands embed the content that students are expected to learn and master at each grade and school level. National content standards are benchmarked at each grade level, which allows for essential KSAV's to be reinforced and expanded throughout the grades. Benchmarks show grade level expectations of what students are able do to demonstrate that they are making progress towards attaining the content standard.

Grade-level benchmarks are unpacked to identify the topics, learning objectives and KSVAs.

Identifying topics from benchmarks

In order to identify the topic from the benchmark, the benchmark needs to be unpacked. When unpacking a benchmark, identify what students will be able to know and do in order to mastered the benchmark.

1. Write out the benchmark that you want to unpack.
2. Write the verbs (skills/actions) – Higher order thinking skills
3. Underline or highlight the big idea (content) in the benchmark. The big idea (content) is the topic derived from the benchmark.
4. Write essential questions that would be engaging for students
5. Develop sub-topics from the big idea (topic)
6. Write learning objectives according to the sub-topics
7. Write lesson topics from the learning objectives



Content Overview

The strand, units and topics are connected and aligned. The topics for each unit were derived from the grade level benchmarks. Unlike the units, the topics differ in grade levels. There are several topics for each unit on the content.

Strand 1: Science as Inquiry

Unit	Topics
1. Thinking Scientifically 2	1. Units of Measurement 2. Geological Equipment

Strand 2: Earth Science

Units	Topics
1. Earth Resources	1. Minerals 2. Fossil Fuels 3. Exploration and Mining of Minerals 4. Exploration and Extraction of Oil and Gas 5. Mining and the Environment
2. Age Dating	1. Age Dating 2. Principles of Stratigraphy
3. Earthquakes and Volcanoes	1. Earthquakes 2. Volcanoes
4. Surface Processes and Groundwater	1. Weathering 2. Erosion 3. Stream Erosion and Deposition 4. Mass Movement 5. Groundwater

Strand	Unit	Topic	Lesson titles
1. Science as Inquiry	1. Thinking Scientifically 2	1. Units of Measurement	1. Unit conversions
		2. Geological Equipment	2. Use of geological hammer and hand lens
			3. Use of compass and clinometer
			4. Use of Global Positioning System
			5. Use of petrographic microscope
2. Earth Science	1. Earth resources	1. Minerals	6. Economic and industrial minerals
			7. Location of economic and industrial mineral deposits in PNG
		2. Fossil fuels	8. Fossil fuels
			9. Location of fossil fuel deposits in PNG
		3. Exploration and mining of minerals	10. Exploration license and minerals prospecting
			11. Methods of mineral exploration
			12. Drilling and logging for minerals
			13. Reserve calculation
			14. Mining economic minerals
			15. Processing of economic minerals
			16. Refining of economic minerals
		4. Exploration and extraction of oil and gas	17. Permitting processes (licenses) and exploration for oil and gas
			18. Drilling and logging for oil and gas
			19. Reserve estimate and well completion
			20. Extraction of crude oil and gas
			21. Refining crude oil
			22. Transportation of minerals, oil and gas
		5. Mining and the Environment	23. Environmental regulations related to mineral, oil and gas extraction and production
			24. Environment Impact Statement
			25. Policies on environmental management of mining activities
			26. Environment management plan
			27. Mine closure plan
			28. Environment rehabilitation
	2. Age dating	1. Age dating	29. Numeric time and geologic time
			30. Relative and absolute time
			31. Comparison of dating methods using a Venn Diagram
			32. Radiometric methods
		2. Principles of stratigraphy	33. Principles of stratigraphy 1
			34. Principles of stratigraphy 2
			35. Applications of stratigraphic principles

Strand	Unit	Topic	Lesson titles
2. Earth Science	3. Earthquakes and volcanoes	1. Earthquakes	36. Elastic rebound theory
			37. Body and surface waves
			38. Travel paths of body waves through the Earth
			39. Evidence of Earth's layering
			40. Seismograph
			41. Earthquake magnitude and intensity
			42. Locating epicenter
			43. Limitations in prediction of earthquakes
			44. Hazards and effects of earthquakes
			45. Seismic risk
		2. Volcanoes	46. Volcanic materials 1
			47. Volcanic materials 2
			48. Magma and lava
			49. Types of volcano and their effects
			50. Types and history of PNG volcanoes
			51. Comparing volcanic features
	4. Surface processes and groundwater	1. Weathering	52. Weathering
			53. Types of weathered materials
		2. Erosion	54. Erosion
			55. Types of soil erosion
			56. Causes of soil erosion
			57. Differential erosion and its features
		3. Stream erosion and deposition	58. Types of stream erosion
			59. Abrasion and dissolution
			60. Sediment transportation by river
			61. Depositional environments
		4. Mass movement	62. Types of mass movement
			63. Types of submarine mass movement
			64. Deposits from mass movement
			65. Causes of mass movement
			66. Mass movement controls
		5. Groundwater	67. Types of groundwater
			68. Groundwater zones
			69. Types of aquifer
			70. Importance and uses of groundwater
			71. Effects of excessive pumping and depletion of groundwater
			72. Well interference

Grade 12 Geology

Teaching Content

Strand 1: Science as Inquiry

Unit 1: Thinking Scientifically 2

Content Standard	**12.1.1** Students will be able to understand and convert units of measurement and use basic geological equipment.
Benchmark	**12.1.1.1** Recognise and compare units of measurement used to quantify objects.

Topic 1: Units of Measurement

Learning Objectives:
By the end of this topic, the students will be able to:

- Identify and convert units of measurement used to quantify objects (e.g., centimetre-gram-second to SI system, inches to centimetres, barrels to cubic metres, kina to dollars).

Essential questions

1. How can we convert unit of measurement when quantifying objects?

Vocabulary: geological equipment, compass, clinometer, Global Positioning System, petrographic microscope

Concepts	Essential Skills	Essential Values and Attitudes
• Units of measurement • Unit conversions	• Converting units of measurement • Compare and contrast	• Appreciate the conversion of units measurement

Content Background

1. Unit conversion

The metric system

The metric system is a system of measurement. It is used for three basic units of measure: metres (m), litres (l) and grams (g).

What makes the metric system so useful is that all three units of measure are based on the powers of ten (including 0.000001, 0.001, 0.01, 0.1, 1, 10, 100, 1000).

Let us examine the metric system conversion chart to understand this idea better.

Let us examine the metric system conversion chart to understand this idea better.

Unit	**kilo-**	**hecto-**	**deka**	**base**	**deci**	**centi-**	**milli-**	**micro**
Values	1, 000	100	10	1	0.01	0.01	0.001	0.000001
Prefix	k-	h-	da-	m g L	d-	c-	m-	mc- or μ-
Values (compared to base	1000 x bigger	100 x bigger	10 x bigger	1	10 x smaller	100 x smaller	1000 x smaller	1,000,000 x smaller

In this chart, the metre (m), gram (g), and litre (l) have a value of 1. Units of measurement to the right of the base unit are becoming smaller and smaller. Units of measure to the left of the base unit are becoming larger and larger. For example, given a metre we notice the following unit conversions to the right of the base unit:

There are 10 dm in a metre,	**There are 100 cm in a metre,**	**There are 1000 mm in a metre,**
Thus, 1 dm = 1/10 m = 0.1 m	Thus, 1 cm = 1/100 m = 0.01 m	Thus, 1 mm = 1/1000 m = 0.001 m

Ratio and proportion method

Example 1: Convert 1.74 m into cm.

To convert metres to centimetres we need to first identify the larger unit. Looking at the Metric System chart we notice that a centimetre is 100 times smaller than a metre.

Thus, 1m = 100cm

Knowing this we can set up a proportion to convert 1.74 m into cm.

Remember! A proportion is a comparison of two equal ratios in which order matters.
On the Left Hand Side (L.H.S.) of the proportion, list the ratio we know. On the Right
Hand Side (R.H.S), list the ratio we are trying to find out. Solve for the unknown value using cross multiplication.

$$\frac{m}{cm} = \frac{m}{cm}$$

$$\frac{1\ m}{100cm} = \frac{1.74m}{xcm}$$

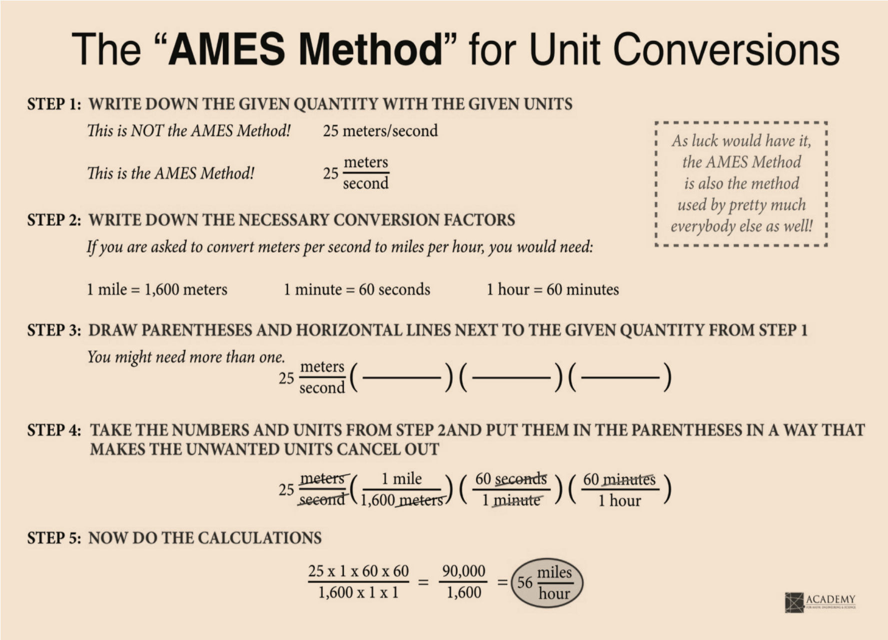
1(x) = 1.74 (100)

x = 174 cm

Thus, there are 174 cm in 1.74 m.

Example 2: Convert 4 g into mg.

First we need to identify the larger unit. Looking at the Metric System Chart we notice that a milligram is 1000 times smaller than a gram.



The "**AMES Method**" for Unit Conversions

STEP 1: WRITE DOWN THE GIVEN QUANTITY WITH THE GIVEN UNITS

This is NOT the AMES Method! 25 meters/second

This is the AMES Method! $25\,\frac{\text{meters}}{\text{second}}$

As luck would have it, the AMES Method is also the method used by pretty much everybody else as well!

STEP 2: WRITE DOWN THE NECESSARY CONVERSION FACTORS

If you are asked to convert meters per second to miles per hour, you would need:

1 mile = 1,600 meters 1 minute = 60 seconds 1 hour = 60 minutes

STEP 3: DRAW PARENTHESES AND HORIZONTAL LINES NEXT TO THE GIVEN QUANTITY FROM STEP 1

You might need more than one.

$$25\,\frac{\text{meters}}{\text{second}}\left(\rule{2em}{0.4pt}\right)\left(\rule{2em}{0.4pt}\right)\left(\rule{2em}{0.4pt}\right)$$

STEP 4: TAKE THE NUMBERS AND UNITS FROM STEP 2AND PUT THEM IN THE PARENTHESES IN A WAY THAT MAKES THE UNWANTED UNITS CANCEL OUT

$$25\,\frac{\cancel{\text{meters}}}{\cancel{\text{second}}}\left(\frac{1\text{ mile}}{1{,}600\ \cancel{\text{meters}}}\right)\left(\frac{60\ \cancel{\text{seconds}}}{1\ \cancel{\text{minute}}}\right)\left(\frac{60\ \cancel{\text{minutes}}}{1\text{ hour}}\right)$$

STEP 5: NOW DO THE CALCULATIONS

$$\frac{25 \text{ x } 1 \text{ x } 60 \text{ x } 60}{1{,}600 \text{ x } 1 \text{ x } 1} = \frac{90{,}000}{1{,}600} = \boxed{56\,\frac{\text{miles}}{\text{hour}}}$$

(Source: http://amesgeology.weebly.com/)

Teaching and Learning Strategies

Teaching Strategies:	**Learning Strategies**
Teachers prepare information (notes, charts, and samples of unit conversions) and ask questions.	Students will use the information provided to answer questions on the unit conversions.
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Identify and convert units of measurement used to quantify objects - STEAM	
Teaching Strategies Teachers will provide the information for students to read, observe and answer questions within a given period of time.	**Learning Strategies** Students read the notes and use the materials available to understand the conversion of units in measurement used to quantify objects.
Recommended Resources: • http://amesgeology.weebly.com/ • Internet	

Unit 1: Thinking Scientifically 2

Content Standard	**12.1.1** Students will be able to understand and convert units of measurement and use basic geological equipment.
Benchmark	**12.1.1.2** Demonstrate the use of geological equipment.

Topic 2: Geological Equipment

Learning Objectives:
By the end of this topic, the students will be able to:

- Demonstrate the use of geological hammer, hand lens, compass and clinometer, Global Positioning System and petrographic microscope to be able to use in the field.

Essential questions

1. How is geological hammer and hand lens used by the geologists?
2. How is compass and clinometer used by the geologists?
3. How is the petrographic microscope used by the geologist?

Vocabulary: geological equipment, compass, clinometer, Global Positioning System, petrographic microscope

Concepts	Essential Skills	Essential Values and Attitudes
• Use of geological equipment	• Using geological hammer • Using hand lens • Using compass and clinometer • Using Global Positioning System • Using of petrographic microscope	• Appreciate the geological equipment • Show desire to learn how to use the geological equipment

Content Background

1. Use of geological hammer and hand lens

Using a hammer in the field

a) Geologists may carry hammers for two primary reasons - to break a piece of rock to get a look at a fresh surface for description or identification, or to collect samples for further work.

b) Generally the advice is to use a hammer as little as possible. Most exposures do not require the use of a hammer, as there are often raw surfaces already exposed. If a sample is to be taken, you should first try to use fragments that have clearly fallen off the exposure.

c) But before you do use a hammer to break a piece of rock at a specific location you must consider if you really need to. You should ask yourself is it appropriate and is there sufficient reason to do so. Whether it is correct to do depends on context.

d) As a participant on an organised field trip, whether you are a professional or a student, you should always ask the fieldtrip leader if hammer usage is permitted at each stop or outcrop.

d) As a participant on an organised field trip, whether you are a professional or a student, you should always ask the fieldtrip leader if hammer usage is permitted at each stop or outcrop.
e) Many times, a weathered surface is more informative than a fresh surface for identifying the minerals present – because the weathering has picked out mineralogical differences.
f) Wherever you do choose to take a sample, always choose a place on the outcrop where the hammer scar will be least visible. Best practice is to attempt to inflict the minimum amount of damage on the outcrop.
g) Hammering is potentially dangerous to both the person yielding the hammer and to people in the area. Tiny detached rock fragments or particles of metal can easily become projectiles and travel considerable distances causing serious injury. This is especially important when groups of people are gathered around outcrops.

Hand Lens

Figure 1. *Geological hand lens*

It takes a little practice to learn how to use a hand lens magnifier. You get the best view of the subject by holding the lens as close to your eye as possible and bringing the object up in front of the lens until it is in focus (Fig. 1). This might be a little bit difficult to get used to if you have not done it this way before, but with a little practice, you will find that you get absolutely the best view of the subject.

Steps on how to use the geological hand lens

(a) Take your lens in whatever hands feel more natural. This will usually be the one for your dominant eye.

(b) Rest your thumb against the cheek bone to hold the lens steady at the correct distance from your eye.

(c) Take the rock in the other hand; position yourself, so that there is a strong light source shining over your shoulder onto the rock.

(d) Bring the rock towards you until the details become sharp and clear.

(e) Move and twist the rock around a little to get use to holding it steady and to get familiar with the rock.

(f) Now observe what you can see on the rock.

Figure 2. *Geologist examining rocks using a hand lens.*
(Source: https://compleatnaturalist.com/how-to-use-a-hand-lens-magnifier/)

2. Use of compass and clinometer

Compass

At first sight it appears confusing to the novice user, for the numbers on the compass dial ascend in an anticlockwise direction. This is because the compass is used to determine dip and dip-direction of surfaces (foliations), and plunge and plunge-direction of lines (lineations). To use the compass one aligns the lid of the compass with the orientation of the surface to be measured (to obtain dip and dip direction), or the edge of the lid of the compass with the orientation of the line (to obtain plunge and plunge direction). The compass must be twisted so that the base of the compass becomes horizontal, as accomplished using the spirit level incorporated in it. The needle of the compass is then freed by using the side button, and allowed to spin until the damping action slows its movement, and then stabilises. The side button is released and the needle is then firmly held in place, allowing the user thereafter to conveniently read the orientation measured. One first reads the scale that shows the angle subtended by the lid of the compass, and then depending on the colour shown (red or black) the end of the compass needle with the corresponding colour. Data are then recorded as (for example) 25°->333° (dip and dip-direction) or (plunge and plunge-direction).

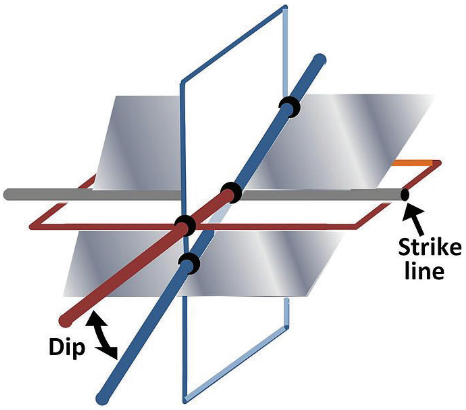


Figure 3. *Strike line and dip of a plane describing attitude relative to a horizontal plane and a vertical plane perpendicular to the strike line*

Clinometer

Inclinometer or clinometer is an instrument used for measuring angles of slope (or tilt), elevation, or depression of an object with respect to gravity's direction. It is also known as a *tilt indicator*, *tilt sensor*, *tilt meter*, *slope alert*, *slope gauge*, *gradient meter*, *gradiometer*, *level gauge*, *level meter*, *declinometer*, and *pitch* and *roll indicator*. Clinometers measure both inclines (positive slopes, as seen by an observer looking upwards) and declines (negative slopes, as seen by an observer looking downward) using units of measure such as degrees or percent).

Inclinometers include examples such as Well's in-clinometer, the essential parts of which are a flat side, or base, on which it stands, and a hollow disc just half filled with some heavy liquid. The glass face of the disc is surrounded by a graduated scale that marks the angle at which the surface of the liquid stands, with reference to the flat base. The zero line is parallel to the base, and when the liquid stands on that line, the flat side is horizontal; the 90 degree is perpendicular to the base, and when the liquid stands on that line, the flat side is perpendicular or plumb. Intervening angles are marked, and, with the aid of simple conversion tables, the instrument indicates the rate of fall per set distance of horizontal measurement, and set distance of the sloping line.

Figure 4. *Stanley Compass with clinometer*
(Source): https://en.wikipedia.org/wiki/Inclinometer#/media/File:Stanley_compass_1.jpg)

Hand-held clinometers are used for a variety of surveying and measurement tasks. In land surveying and mapping, a clinometer can provide a rapid measurement of the slope of a geographic feature, or used for cave survey. In prospecting for minerals, clinometers are used to measure the strike and dip of geologic formations. In forestry, tree height measurement can be done with a clinometer using standardised methods.

3. Use of Global Positioning System

The GPS system consists of a network of 24 active satellites (and 8 spares) located nearly 20,000 km above the earth's surface. Each satellite broadcasts different signals which can be tracked by a GPS receiver on earth, which are then analysed by the GPS receiver to determine its precise location. The signals operate in all weather conditions but cannot penetrate through solid objects, so GPS receivers perform best when they have a clear view of the sky.

GPS receivers come in all different shapes and sizes, are widespread and are affordable. Today, GPS receivers can be found in watches, phones, tablets, computers, cars and a wide variety of other devices.

What can you use GPS units for?

Measuring location (latitude, longitude – elevation is also included) – this is termed *Waypoints* and is the most important function.

Using a GPS

General - Do´s and Do not's

Do´s

- Make sure the unit has batteries installed – 2x AA (+ always carry spare batteries!)
- Always write down location coordinates, elevation and waypoint number – even if you plan to download data.
- Always use a GPS to record location data!

Figure 5. *A GPS receiver*

Do not's

- Use a GPS indoors – it will not work!
- Use a GPS next to tall buildings or in dense forest – you may get problems in receiving the signal
- Use a GPS with your fingers or head covering the receiver – the area just above the word "Etrex" on the front of Garmin units. This will also block the signal.

Ensure Standard GPS settings are used [NB: This only needs to be done once – upon receipt of GPS units, prior to use in field survey. After settings are complete no further changes should be made]

Standard settings procedure: [NB: This can be done indoors; no satellite signal is needed] a. Switch on GPS by pressing Power key. Press Page key several times until the Main Menu screen appears.

(a) Switch on GPS by pressing power key
(b) Press Page key several times until the Main Menu screen appears
(c) Press the Down / Up keys to select Setup
(d) Press the Enter key to open the Setup Menu
(e) Press the Down / Up keys to select Units. The Units option contains the key settings that you should check / change.
(f) Use the Enter key to select a category, then the Up / Down Keys to select the correct option within a category. Finally, press Enter key to save change
(g) Repeat step *f* for each Units category

NOTE: Follow the link below for more information on the use and function of GPS. https://rusttracker.cimmyt.org/wp-content/uploads/2011/11/GPS-survey-protocols.pdf

4. Use of Petrographic Microscope

A petrographic microscope is used to observe a series of characteristics in a mineral which reflect its properties and allow geologists to identify it.

The petrographic microscope is a compound microscope which can work with plane polarised light, meaning that it has some peculiarities.

This is always done with transmitted plane polarised light, meaning that the polariser must be inserted.

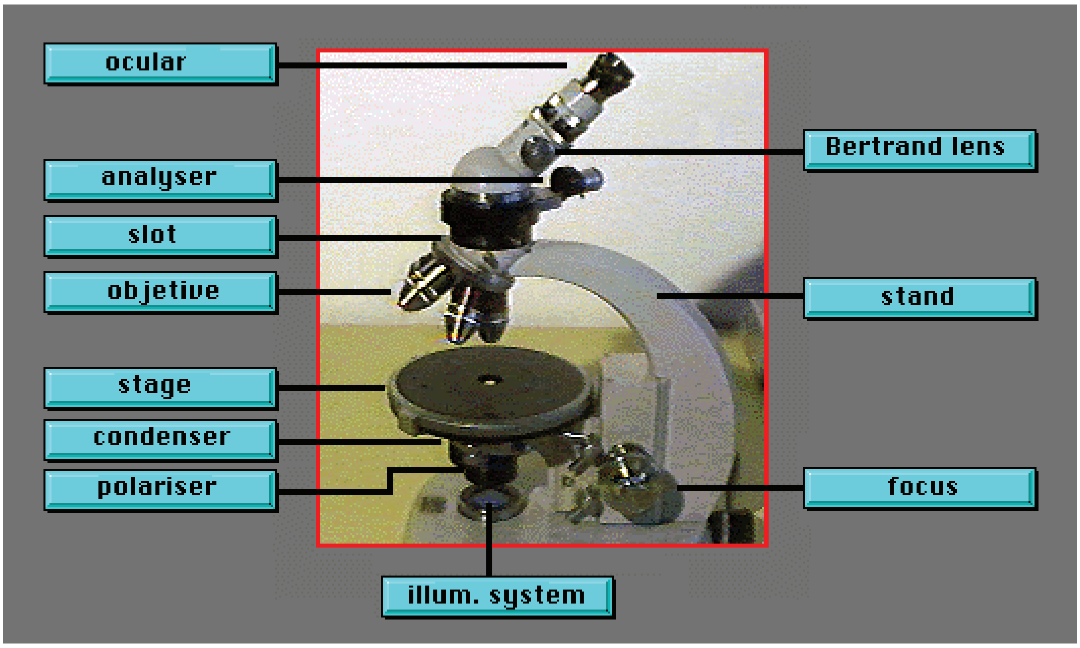


Figure 6. *Petrographic microscope* (Source: http://www.edafologia.net/optmine/intro/microscw.htm)

Putting the microscope in operation

(a) Match the line voltage selector switch to local mains voltage
(b) Switch the light source.
(c) Place a specimen slide on the stage.
(d) Remove the Bertrand lens and the analyser from the light path.
(e) Coarse focus with the 10X objective.
(f) Make interpupillary and diopter adjustments.
(g) Set the analyser to optimum extinction position.
(h) Centre the condenser.
(i) Centre the stage.
(j) Centre objectives other than 10X.
(k) Swing the desired objective.
(l) Set the condenser, analyser and Bertrand lens correctly according to the microscopic purpose.
(m) Fine focus.
(n) Adjust aperture iris diaphragm and field iris diaphragm.

Table 1. *Adjustment of Illumination System*

Microscope application	**Objective**	**Bertrand lens in intermediate polarising attachment**	**Condenser top lens**
Orthoscopic observation	4X to 100X	out	out
Conoscopic observation	20X to 100X	in	in

Teaching and Learning Strategies

Teaching Strategies:	**Learning Strategies**
Teachers prepare information (notes, charts, and samples of geological equipment) and ask questions.	Students will use the information provided to answer questions on the geological equipment.

STEAM Approach

Learning Objective: By the end of the topic, students will be able to;

- Identify and make models of equipment used by geologists - STEAM

Teaching Strategies	**Learning Strategies**
Teachers will provide the information for students to read, observe and answer questions within a given period of time.	Students read the notes and use the materials available to understand the equipment used by geologists.

Recommended Resources:

- https://en.wikipedia.org/wiki/Inclinometer
- Internet

Strand 2: Earth Science

UNIT 1: Earth Resources

Content Standard	**12.2.1** Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.
Benchmark	**12.2.1.1** Examine the common minerals, their formations and the uses of economic minerals.

Topic 1: Minerals

Learning Objectives:
By the end of this topic, the students will be able to:

- Describe the difference between economic and industrial minerals.
- Analyse examples of economic and industrial minerals.
- Assess locations of economic and industrial minerals deposits in PNG.

Essential questions

1. What are economic minerals?
2. What are industrial minerals?
3. Where are economic mineral deposits located in PNG?

Vocabulary: economic minerals, industrial minerals, gold, copper, silver, limestone, iron-sands

Concepts	Essential Skills	Essential Values and Attitudes
• Economic minerals • Industrial minerals • Gold, copper, silver • Limestone, iron-sands	• Making generalisations • Analysing • Visualising • Reasoning	Open-minded, with a desire to learn

Content Background

1. Economic and industrial minerals

Minerals are the building blocks of rocks. They can indicate the environments that rocks were created in, exposed to, or sourced from. Several minerals act as the world's resources for metals (gold, silver, metal-sulphides, and rare earth elements). They are also used in jewellery, art, and decorations.

Economic minerals include gold, silver, copper, zinc, aluminium, etc. These are exploited, extracted and used locally or sold for money. Examples of industrial minerals are limestone, iron-sands, shale, and granite. These category of minerals are used for construction, buildings, roads, etc.

Various minerals have different economic values and uses in the history of mankind. Copper serves to illustrate.

Pure copper is red-orange in colour. When it is exposed to air it darkens to a brown colour and if exposed to air and water, it becomes a blue-green colour called *verdigris*. The only two metals used by humans before copper were gold and iron. Copper is believed to have been in used since ancient times over 10,000 years ago.

Figure 1. *Gold – an example of an economic mineral*

Figure 2. *Limestone – an example of an industrial mineral*

Copper is an essential nutrient to all living organisms. Copper deficiency in the human body can cause serious health issues. Due to its versatility and durability, copper is referred to as *man's eternal metal*. Numerous important copper alloys have been produced over human history. Brass is a mixture of copper and zinc, bronze is an alloy of copper and tin. While cupronickel is a combination of copper and nickel.

Copper is also found in TVs, radios, washers, dryers and some cookware. Over 81 tonnes of copper was used to build the Statue of Liberty in USA. Copper is a natural anti-bacterial. To prevent the spread of bacteria, brass door knobs and hand rails are often used in public buildings. Bacteria will not grow on copper. It has been used for centuries to line outside of ship hulls so that barnacles and mussels do not grow on the boat hulls. Nearly 80 percent of all the copper ever produced is still in use today due to the fact that copper is 100 percent recyclable and retains 95 percent of its original value.

Simple models of mineral formation

The various processes that lead to the formation of mineral deposits vary from mineral to mineral. Sometimes deposition of one will be associated with another, which is typically seen in the mineral deposit models of the circum-Pacific region. Here, silver serves to illustrate.

Simple models of mineral formation

The various processes that lead to the formation of mineral deposits vary from mineral to mineral. Sometimes deposition of one will be associated with another, which is typically seen in the mineral deposit models of the circum-Pacific region. Here, silver serves to illustrate.

Apart from gold, metals such as copper, lead, zinc and silver form compounds with sulphur called *sulphides*. Deep in the Earth's crust, hot fluids, in the form of a brine at 350°C, circulate and dissolve these metals, collecting and concentrating them. This brine comes up to the Earth's surface via holes in the seafloor called *vents* or through the continental crust. Once in contact with either sea water or cooler rocks close to the surface, the metal sulphides precipitate out as various minerals, for example, chalcopyrite (copper sulphide), galena (lead sulphide) and sphalerite (zinc sulphide). Silver precipitates as a mixture within the other sulphides.

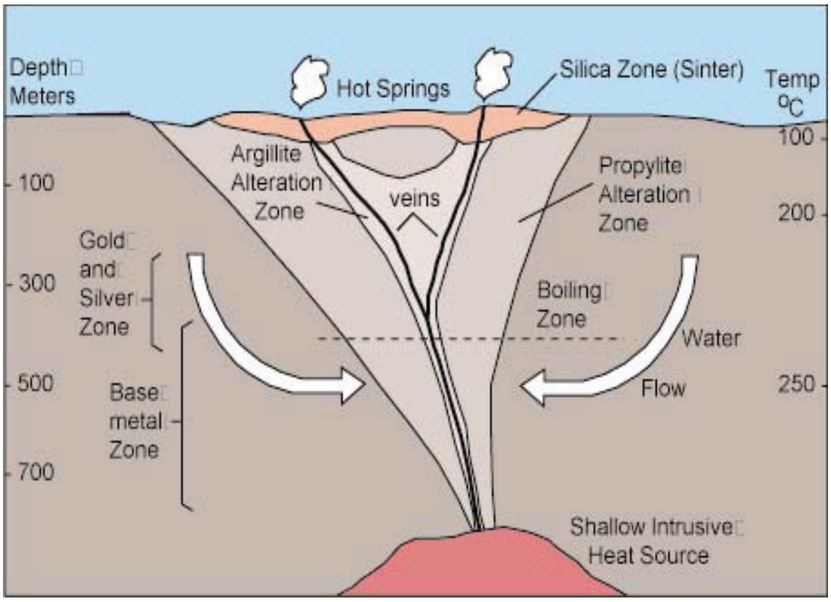


Figure 3. *Simple model of gold, silver and base metals in an epithermal (close to heat source) deposit* (Source: http://earthsci.org/mineral/mindep/vein/vein.html)

These metals are present in the Earth's crust in only very small amounts. Silver is present at approximately five parts per million. Silver is also found in native form as an alloy with gold and in ores containing sulphur, arsenic, antimony or chlorine. The principal sources of the world's silver are the ores of copper, copper-nickel, lead, and lead-zinc, obtained from Mexico (the leading producer), China, Australia, Poland, Chile, Peru, United States and Argentina. Silver is primarily produced as a by-product of electrolytic copper refining as well as gold, nickel and zinc refining. Around two-thirds of the silver obtained today is a by-product of copper, lead, and zinc mining.

Due to silver's close association with gold, PNG's major silver producers are Porgera, Lihir and Hidden Valley gold mines. The Ok Tedi copper mine produced over 930,000 ounces of silver as a by-product in 2013. Significant silver resources also occur in the Solwara-1 undersea massive sulphide deposits in the Bismarck Sea.

Examples of mineral ores

There are numerous examples of mineral ores. For example, the ore from which aluminium metal is produced is bauxite, lead from galena and copper from chalcopyrite. Coal serves to illustrate further as an example.

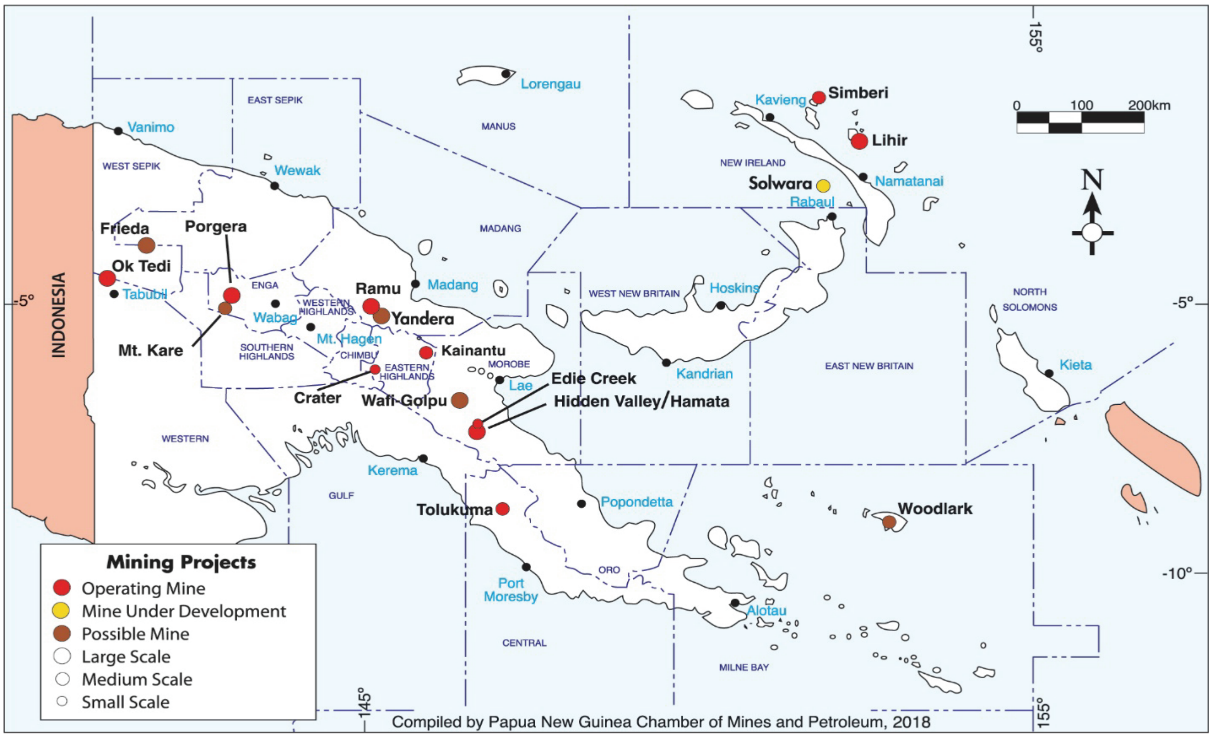
Coal is made largely of carbon but also features other elements such as hydrogen, oxygen, sulphur and nitrogen. Coal is classified into four main types: lignite, sub-bituminous, bituminous, anthracite and the coal value is determined by the amount of the carbon it contains. Lignite contains only around 60 to 75 percent carbon, while anthracite contains more than 92 percent carbon. Anthracite is a hard, shiny, black coal that burns with a blue, smokeless flame.

While most forms of coal are sedimentary rocks, anthracite is a metamorphic rock due to its significant changes in characteristics due to pressure and heat. Coal was originally swamp plants that became covered by sediments. A combination of pressure, heat and time (300 million years) created various kinds of coal.

Coal is mined in more than 100 countries. Coal is currently the world’s largest source of energy for the production of electricity. The world's iron and steel industry depends on the use of coal. Coal takes millions of years to create and therefore it belongs to non-renewable energy sources. Coal mining and the burning of coal pose environmental effects, these include waste products such as overburden and emissions from the burning of coal such as carbon dioxide and sulphur.

2. Location of economic and industrial minerals in PNG

Nearly all the economic and industrial minerals are found on the island of New Guinea. Some of these have been developed into mines (e.g. copper-gold in Grasberg in Indonesian Papua, copper-gold in Ok Tedi, nickel-cobalt in Ramu, gold on Lihir Island, base metals in Solwara-1), others are in various stages of exploration (grassroots, advanced, feasibility, scoping study, bankable feasibility study, and construction stages). Others are still in the ground and yet to be found. Figure 1 shows the mineral projects in Papua New Guinea. Some mines have been closed (e.g. Panguna, Misima).



Compiled by Papua New Guinea Chamber of Mines and Petroleum, 2018

Figure 4. *Mineral projects in Papua New Guinea.* Map courtesy of PNG Chamber of Mines and Petroleum.

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (notes, charts, and samples of economic and industrial minerals) and ask questions on the economic and industrial minerals. Teachers can take students out for an excursion to the nearest mine or quarry project (if possible).	Students will use the information provided to answer questions on the economic and industrial minerals, and where they can be located in PNG.
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Visualise, compare and contrast economic and industrial minerals - STEAM	
Teaching Strategies Teachers will provide the information for students to read, observe and answer questions within a given period of time.	**Learning Strategies** Students read the notes and use the materials available to understand the difference between economic and industrial minerals.

Recommended Resources:

- Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p
- http://www.ispatguru.com/natural-gas-its-characteristics-and-safety-requirements/
- https://www.OilScams.org
- Internet
- PNG OresomeResources.com – Minerals and Energy Education

Unit 1: Earth Resources	
Content Standard	**12.2.1** Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.
Benchmark	**12.2.1.2** Analyse the formation and characteristics of fossil fuels such as crude oil and natural gas.
Topic 2: Fossil Fuels	

Learning Objectives:

By the end of this topic, the students will be able to:

- Describe what fossil fuels (coal, crude oil, natural gas) are.
- Assess deposits of coal, crude oil and natural gas in PNG.

Essential questions

1. What are fossil fuels?
2. Where are fossil fuel deposits located in PNG?
3. What is the common difference between coal, crude oil and natural gas?

Vocabulary: fossil fuels, coal, crude oil, natural gas

Concepts	Essential Skills	Essential Values and Attitudes
• Fossil fuels • Coal • Crude oil • Natural gas	• Making generalisations • Comparing and contrasting • Visualising • Reasoning	Open-minded, with a desire to learn

Content Background

1. Fossil fuels

Fossil fuels are fuels formed by natural processes principally by decomposition of buried dead organisms in the absence of oxygen. They energy contained originated in photosynthesis processes in ancient times. Fossil fuels contain high percentages of carbon and include petroleum, coal, and natural gas. Commonly used derivatives of fossil fuels include kerosene and propane. Fossil fuels range from volatile materials with low carbon-to-hydrogen ratios (like methane), to liquids (like petroleum), to non-volatile materials composed of almost pure carbon, like anthracite coal. Methane can be found in hydrocarbon fields either alone, associated with oil, or in the form of methane clathrates.

- Coal: It is the primary fuel for the production of electricity.
- Oil: Oil is the primary source for the world's transportation
- Natural Gas: They energy of some countries is fueled by natural gas.

2. Location of fossil fuel deposits in PNG

Coal deposits are found in the Gulf and Morobe Provinces and are currently being explored. Other places in the country are likely to deposits of this fossil fuel. However, there is no operating coal mines in the country unlike over neighbours Australia and Indonesia.

Nearly all of the oil and gas fields in Papua New Guinea are located in the Papuan Basin – the fold belt and foreland areas, as shown in Figure 4. Both oil and gas have been produced from some of these fields. Oil is piped and exported as crude via the Kumul terminal located some 40 km offshore in the Gulf of Papua. A certain portion of the crude oil is refined at the Napa Napa refinery in Port Moresby.

Natural gas is conditioned at a plant in Hides in the Papua New Guinea Highlands and then transported over 700 km via pipeline to an LNG plant located approximately 20 km northwest of Port Moresby. The gas is then liquefied at the LNG plant prior to loading onto LNG carriers to be shipped to international markets.

The project aims to provide a long-term supply of LNG to four major customers in the Asia region. Production from the first LNG train started in April 2014 and the first shipment of LNG to Japan occurred in May 2014. By the end of June 2014, seven LNG cargoes had been shipped. Other gas projects currently being developed in Papua New Guinea include: The Gulf LNG Project based on Elk-Antelope fields gas and condensate; the Stanley field gas and condensate recovery project in Western Province; Other Western Province gas aggregation projects; and Expansion of the PNG LNG project.

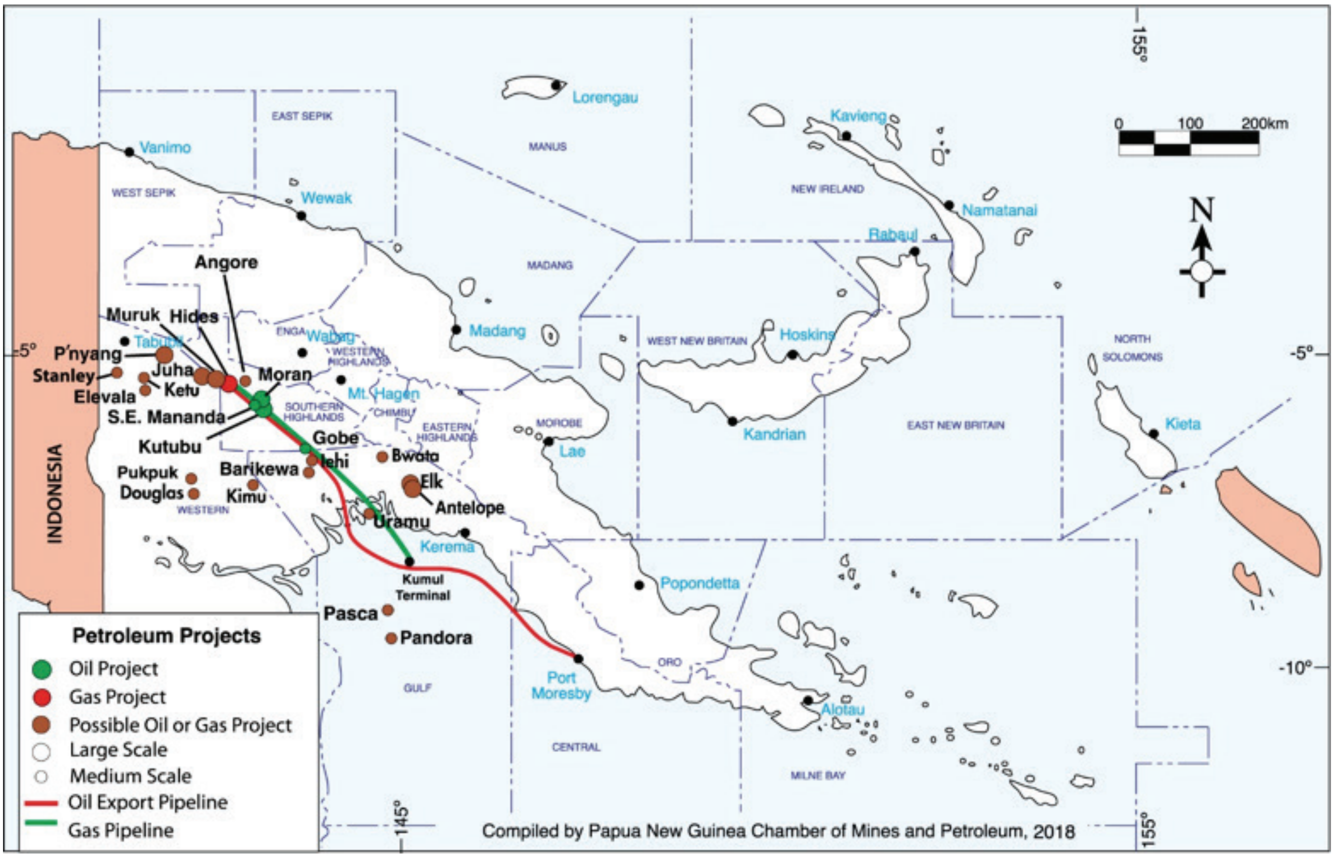


Figure 1. Oil and gas projects in Papua New Guinea. Map courtesy of PNG Chamber of Mines and Petroleum.

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (notes, charts on coal, oil and gas samples) and ask questions on coal, crude oil and natural gas.	Students will use the information provided to answer questions on fossils fuels (coal, crude oil natural gas) and their deposit locations in PNG
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Visualise, compare coal, crude oil and natural gas - STEAM	
Teaching Strategies Teachers will provide the information for students to read, observe and answer questions within a given period of time.	**Learning Strategies** Students read the notes and use the materials available to understand the difference between coal, crude oil and natural gas.
Recommended Resources: • Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p • http://www.ispatguru.com/natural-gas-its-characteristics-and-safety-requirements/ • https://www.OilScams.org • PNG OresomeResources.com – Minerals and Energy Education	

Unit 1: Earth Resources

Content Standard	**12.2.1** Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.
Benchmark	**12.2.1.3** Examine and compare the exploration and mining of minerals.

Topic 3: Exploration and Mining of Minerals

Learning Objectives:

By the end of this topic, the students will be able to:

- Describe the processes involved in the issuing of a mineral exploration license.
- Asses the different methods used in mineral exploration.
- Describe the processes involved in mineral prospecting and drilling.
- Asses the different techniques used in mining, processing, refining and transportation of minerals.

Essential questions

1. What are the processes involved in the issuing of mineral exploration licences?
2. What are some of the methods involved in mineral exploration?
3. How economic mineral ores are mined, processed and refined?
4. How economic mineral ores and their refined products transported?

Vocabulary: Exploration license, drilling, logging, mining, extracting, processing, refining

Concepts	Essential Skills	Essential Values and Attitudes
• Mineral exploration license • Mineral exploration • Drilling and logging • Mining, processing, refining	• Making generalisations • Analysing • Visualising • Reasoning	• Open-minded, with a desire to learn

Content Background

1. Exploration license and minerals prospecting

Exploration is the process of searching for deposits of minerals in the ground. The information and data gathered during exploration is used to assess the size and quality of a mineral deposit and determine if it can be developed into a mine.

All minerals in Papua New Guinea (PNG) are owned by the State. The PNG Government encourages mineral explorers to find and develop mineral resources, which deliver significant economic benefits to the State and its people. All exploration activities must be conducted under the Mineral
Resources Authority (MRA), a Government Agency that ensures companies operate responsibly.

If a company wishes to carry out exploration, then certain information has to be lodged with the MRA on their application forms. The MRA will consider this information and based on the merits of the application, will grant an Exploration Licence for a certain period of time. Companies are required to regularly report back to the MRA stating what work they completed and provide exploration results and declare how much money they have spent.

Since MRA is a Government Agency, all its functions are executed on behalf of the Government of PNG. The Mining Act of 1992 is administered by the MRA.

All areas of interest subject to mineral exploration by either individuals and/or companies are required to apply to the MRA for a mineral tenement over the area under exploration. Applicants must follow an application process together with a fee. A tenement is a permit, claim or licence over a particular area of ground that may be granted by the MRA authorizing prospecting, exploration, mining and/or mineral processing, depending on the type of tenement applied for and the relevant activities expected to take place.

There are various types of Mining Tenements which are issued by the Mining Minister on recommendation from the Mining Advisory Council under the Mining Act 1992. Some of these different types of tenements are:

Exploration Licence (EL) – granted for a period not exceeding two years and consisting of a set of connecting sub-blocks each 3.41 km2 in size. Companies can only conduct exploration activities under this licence, typically sampling and drilling.

Mining Lease (ML) - issued for small to medium scale alluvial and hard rock mining operations for a term not exceeding 20 years, but can be renewed for periods not exceeding 10 years.

Special Mining Lease (SML) – issued to holders of ELs that are party to a Mining Development Contract (MDC) with the State for large scale mining operations for a period of up to 40 years with extension periods not exceeding 20 years.

Alluvial Mining Lease (AML) – Granted to natural persons as citizens or land groups who owns the land that is a river bed or adjoining banks.

Environmental and social responsibility - All exploration activities must be carried out in a responsible manner to avoid harm to the environment. Companies pay a security deposit to satisfy licence requirements and are required to complete rehabilitation of areas disturbed during exploration.

Exploration licence holders must always have good relations with the landholder, often through a land access agreement. Meetings known as Mine Warden meetings are held periodically with the landholders and company representatives under supervision from Mine Wardens representing the MRA.

2. Methods of mineral exploration

Exploration is initially conducted over wide areas and becomes more focused and intense once more data and information are gathered to identify potential mineral resources. Exploration can involve a range of techniques and is generally carried out in stages.

Exploration target identification - geophysicists study satellite images and data which can be computer manipulated to provide more information. Government department geological maps and databases are referenced to determine where geological anomalies may occur. A decision is made to pursue land-based exploration according to the merits of the findings.

Permission to explore - landowners and government representatives are consulted to seek permission to explore and ensure that all legislative requirements are met. Exploration permits are awarded stating specific areas where exploration can occur.

Aerial magnetic surveys - companies conduct aeromagnetic surveys in a grid pattern using aircraft over a broad area under the guidance of a geophysicist, where geological features and structures below the surface are identified. The Earth's magnetic, gravitational and electrical properties are measured. The information is processed to prepare aeromagnetic and gravity maps highlighting potential targets for detailed exploration on the ground.

Surface sampling and mapping - geologists conduct site visits to meet the landholders and community representatives and investigate rock outcrops to map and measure the surface rocks through identification and structural orientation. Stream sediment, soil and rock chip samples are taken for geochemical analysis to determine the mineral concentrations. Exploration for gold, the most popular mineral in PNG, is often being extracted by artisanal miners along creek beds and through their local knowledge, valuable data can be obtained.

Phases of follow-up investigations - the reconnaissance stage may identify areas requiring further investigation. Additional samples and/or ground geophysical surveys over anomalous areas may be required. In PNG, the difficult terrain may require that access tracks will have to be cut into focus areas and compensation for affected vegetation will have to be paid to the Landowner. A detailed geological database and maps showing geological features, observations, sampling positions and mineral analysis results will be developed by this stage.

3. Drilling and logging for minerals

Drilling - If an area is discovered with positive results obtained from one or more of the previous techniques, then additional exploration would usually involve drilling to collect rock chip or core samples below the surface. A geologist will supervise the drilling and sampling and record observations of the extracted material. Drilling is expensive, so the number, position, orientation and depth of the holes drilled to test an area of interest is carefully planned. Explorers in PNG normally start drilling programmes using lightweight, portable drill rigs and then progress to larger and deeper drilling programmes if required. Surveyors record the precise position of the drill holes.

Geological modelling and mineral resource estimation - All data collected from the drilling and sampling is uploaded by a resource geologist into a computerised database and then, using sophisticated software, a three dimensional model displaying the mineral grades, tonnages and shape of the mineral resource is created. Further modelling is carried out to design a mining plan. Resource and/or reserve estimation is further discussed in a separate lesson.

Bulk sampling - Trenches or pits are excavated in defined areas of interest to obtain larger samples for further geochemical analysis and density measurements. Bulk sampling is labour intensive and is generally only required as part of feasibility investigations for a proposal to start mining.

4. Reserve calculation

After a possible ore deposit has been discovered, there are many factors which must be considered before mining can commence. The size and richness of the deposit are important but these are only two of the factors which determine whether or not mining can make a profit. Economic factors must also be considered, together with the equally important political and social implications of developing the deposit. The effects and inter-relationships of these factors are considered in this lesson.

The location of ore deposits by various techniques is an important and costly operation. Once an ore deposit has been located it is necessary to determine the quantity of material which can be recovered economically. This is called the ore reserve.

Before an ore reserve can be calculated we need to know: the grade of ore; its tonnage; the most suitable mining and treatment methods and their cost; environmental impact requirements; marketing and administration costs; and the cost of facilities which the mining company may be required to build – housing, town services, roads, and ports.

Grade - Critical factors in the definition of an ore reserve are tonnage and grade. Grade is a measure of the concentration of the valuable part of the ore. The unit of grade measurement varies from metal to metal, and is related to the form in which the metal or mineral is used by industry. Gold, silver and platinum are measured in grams of metal per tonne of ore, whereas metals such as copper, zinc, and lead are measured in percentages by weight of metal in the ore. Metals such as uranium, chromium or tungsten are measured in percentage by weight of the metal oxide present in the ore.

Tonnage - Tonnage is as important as grade. For an ore deposit to be worth mining in economic terms, the total value of the deposit ‘in the ground’ must exceed the total cost of recovery. Value in the ground is defined as tonnes multiplied by value of recoverable mineral in each tonne. The cost of recovery includes building and running the mine, treatment plant, smelter, town, water and power supply, and the cost of transporting the product to the buyer.

Mining and treatment - Mining and metallurgical costs influence an ore reserve estimate. Near surface ore bodies may be mined cheaply by open cut mining methods, whereas deep ore bodies may demand very costly underground mining methods. Hence it is possible to mine ores of lower grade by open cut but not by underground methods. Another factor which must be considered is the cost of separating the ore mineral or metal from its host. Some ores may yield their valuable component readily while others may be difficult to treat due to a complex association between the valuable metal or mineral and the host rock. In some cases other elements may contaminate the final product and be expensive to remove. For example, the presence of small amounts of iron in tin ore minerals causes a problem when smelting because of the formation of iron-tin alloys which build up in the smelter. Another example is the presence of lead in copper minerals.

Selling price - The market for minerals and metals, that is the price which buyers are willing to pay, frequently exerts an important influence on the calculation of ore reserves. If the market price is low, only the higher grade portion of the ore body may be mined so that a satisfactory financial return on the investment can be obtained. Thus difficult market conditions may lead to a reduction in the portion of a mineral deposit which can be included in an ore reserve. The entry into a market of metal or mineral products from countries with low labour or fuel costs, or where facilities are provided by governments at less than the actual costs, may lead to a similar deposit becoming uneconomical in a high cost country such as Papua New Guinea.

Infrastructure - The requirement imposed on mining companies engaged in major development projects to provide facilities such as towns, roads and ports is a cost which must be considered when estimating ore reserves. These facilities are called infrastructure. Many ore deposits are found in remote areas where town and transport facilities are not available. These must be provided so that the minerals can be mined and move to the market place. For small mines the infrastructure may not be great, but for large deposits all of the following services may be required – mining towns, ports, and roads.

5. Mining economic minerals

Mining of economic minerals can be divided into several categories. All of these types are important industries which can provide employment and earn export money for a nation. Mining operations are controlled by laws and regulations (Mining and Petroleum Acts) which are concerned with factors such as safety, mining and processing, environment, leases, royalties, taxes and conservation, and are revised as required. Government Agents or Mines Inspectors and Wardens operate to ensure that these legal requirements are met. Reports describing the mining activities are submitted to appropriate authorities.

Surface mining methods

Although many factors must be considered in selecting the method of mining, the most important factor is the nature of the deposit. In some cases it may be necessary to change from one method to another, for example, from open-cut to underground mining if the deposit becomes too deep.

If the mineral deposit is on or near the surface, open-air mining techniques may be applied. They have the advantage of natural ventilation and light and may be adopted for working small deposits such as road metal quarries, or very large ones such as the Lihir gold mine on Lihir Island, New Ireland. Open-air mining is not always convenient and is affected by weather conditions such as high rainfall. The Ok Tedi copper-gold deposit is an example of this. There are also environmental problems such as noise, dust and waste disposal associated with this method of mining. Nevertheless by far the greatest tonnage of material is recovered by surface mining methods.

Methods of surface mining may be divided into two classes: those dependent upon water and usually used for alluvial or placer deposits such as alluvial gold or beach sands, and dry methods for hard rock mining or coal.

Wet mining methods

Hydraulicking or sluicing. For placer deposits where water is available and the bedrock is suitable, water under pressure is directed through nozzles to break the ground and wash the mixture of ore and water to a concentrating plant. This method, which can be used for small or relatively large alluvial deposits, has been of great value in the past but is less common today because there are fewer deposits suitable for this method of working.

Figure 1. *The sluicing method of mining.* Image courtesy of PNG Chamber of Mines and Petroleum.

Sluicing may also be used to remove soft waste material covering valuable hard rock deposits in preparation for later mining.

Dredging. Dredging is an important mining technique. It is used for mining gold deposits under water, for example, the early gold workings in the Bulolo-Wau area of the Morobe goldfields. It is also used in other industrial mineral areas such as removing silt from rivers, improving harbours, and land reclamation. Generally, dredging is used to recover material below the surface of water. Where an appropriate body of water does not exist, the first stage of the operation is to establish the dredging pond.

Figure 2. *Remnants of dredging equipment used for mining in the Morobe goldfields in the 1960s.* Photo courtesy of PNG Chamber of Mines and Petroleum.

There are different types of dredging operations but mined material is normally concentrated on the floating platform, and the unwanted material, called *tailings*, is discharged to the rear of the dredge.

Dry mining methods

Open-cut mining. Dry methods of surface mining are generally referred to as open-cut or open pit mining and include bench mining, strip mining and quarrying. The most suitable deposits for this method of mining are massive, thick bedded or tabular deposits which extend more or less horizontally. The amount of overlying rock which must be removed is an important factor. This is called the *overburden* and, as the overburden thickness increases, so must the size or value of the deposit so that the project can be an economical operation. If the cost of removing the overburden exceeds the final sale vale of the product mined, the deposit cannot be exploited.

Although single bench mining may be employed, most open-cut mines are multi-bench. The size of the benches is designed to meet the needs of the working area for drilling crews, storage of broken ore, safety in case of bench slope failure, ore loading operations, and to form a means of transport by vehicles, or in some instances conveyor belt, of the mined products from the pit.

Normally explosives are required to break both ore and overburden to the required degree of fragmentation. However, in some instances, such as in coal mines, overburden may be removed after ripping by machines. Because of its softness brown coal may be mined directly by bucket wheels or dredges.

Figure 3. *Open-cut mining at Ok Tedi.* Photo courtesy of PNG Chamber of Mines and Petroleum.

Strip mining. This is a special form of open-cut mining and is used for mining coal and other selected deposits such as iron ores. Mining begins by using a dragline to uncover a strip of coal the full width of the deposit. The coal is then recovered at the same time as the overburden is being removed from a further strip of coal. The overburden or waste rock is placed back into the area mined so that the area can be reclaimed as mining proceeds.

Quarrying. Quarrying is the term often used for the mining of materials such as limestone, aggregate and building stone. The site selected is usually a hill or valley slope because the mined material can be more easily moved downhill from the place of mining, through the treatment plant, to the point of transport from the site.

Underground mining methods

Some mineral deposits are not favourable to open-cut mining because the dip of the deposit is steeply inclined or the depth of the overburden which must be removed is too great. In such cases underground mining must be used. Underground mining costs more than open-cut mining so it cannot be used on low grade or low value deposits. Further, because of the size of the operation needed to develop the mine, production may not be possible for a considerable time after mining operations begin.

Figure 4. *Entrance (adit) to underground mine at Tolukuma mine.* Photo courtesy of PNG Chamber of Mines and Petroleum

The first procedure is to obtain access to the deposit. Many factors control the position of the access tunnel. Access tunnels may be horizontal, or nearly so, and they are called *adits*, or vertical, or nearly so, when they are called *shafts*. In several modern mines a spiral roadway, called a *decline*, is constructed from surface underground to the ore body. These openings are made by drilling and blasting.

The opening is the most important part of the mine, and to ensure its permanence and safety, it is often lined with concrete. Through this opening will pass all the men to work in the mine, all the air for ventilation, power and water, and materials necessary for the operation of the mine. The adit or shaft is also used to haul the mined material to the surface.

Offshore mining

Increased is being shown in deposits of minerals which occur on the sea floor. Some deposit of sand, gravel and other minerals are being recovered by dredging. Manganese nodules, which occur on some areas of the deep ocean basins and contain varying proportions of copper, cobalt and nickel, are being investigated. The cost of offshore mining is much higher than onshore mining. However, further developments can be anticipated as onshore reserves are depleted.

An example of an offshore mining is the Solwara-1 project located in the Bismarck near New Ireland. Gold, copper and other base metals deposits have been discovered and will be developed. Under water mining technology have been built and tested and will be used. When this happens, it will the first successful under water mining.

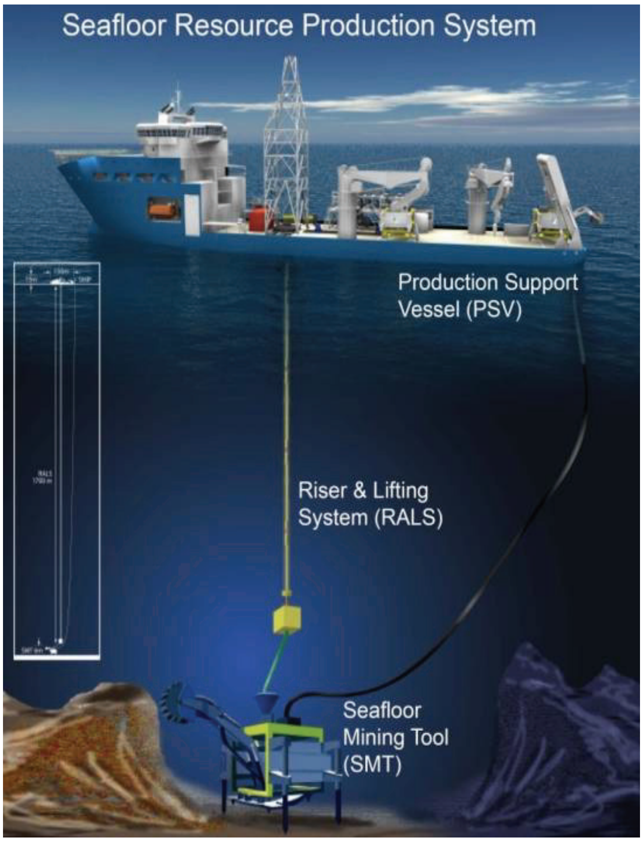


Figure 5. *Seafloor mining scheme.* Image after Nautilus Minerals.

Seawater may also be used as a source of salts. It is pumped into ponds, and the salt is harvested after the water has evaporated.

6. Processing of economic minerals

What happens to the ore after it is mined? After mining, the ore must be treated so that its valuable component can be obtained. Usually the metal is present in the ore only in low concentrations. Before smelting can take place the concentration must be increased. Sometimes small amounts of impurities must be removed before the material can be sold. For example, iron ores which contain sulphur, phosphorus, aluminium, titanium, copper or nickel must have these elements removed before they can be smelted. The physical processes which are involved are called *concentration* processes.

Liberation - The first stage in the concentration process is to crush and grind the ore to liberate the mineral grains of the economic minerals from associated gangue or waste minerals. In some cases liberation may have taken place by natural processes, for example, alluvial deposits and beach sands where the grains are not bonded together. For most, however, the first way of fracturing the ore is by use of explosives to obtain pieces of a size suitable for further treatment. The next stage is crushing. After crushing, the material is passed through large sieves or screens to make sure that it is the correct size.

If further particle size reduction is required, rod or ball mills may be used to grind the ore to the required particle size. For grinding, the ore is commonly mixed with water so that it will flow through the mill. Classifiers are used to stop large particles from passing through with the ore.

Figure 6. *Crushers and ball mills used at the Hidden Valley mine, Morobe Province (Images after MMJV).*

Concentration - A wide range of processes is available for separating the economic mineral from gangue minerals or, in the case of material such as coal, for the removal of impurities. Differences in chemical or physical properties allow the ore minerals to be separated from the gangue minerals.

Froth flotation - Froth flotation is a process developed in Australia and now applied throughout the world. It is often used to separate sulphide ore minerals from gangue minerals because they have different surface properties. The crushed ore is put in a froth flotation cell with a mixture of water and chemicals. The chemicals are usually complex organic molecules which are called collectors and frothers. The collector sticks to the surface of the mineral to be concentrated. The frother is like a detergent and makes a froth which floats on the surface of the tank. Air is forced through the bottom of the tank to agitate the mixture. The collector makes the ore minerals stick to air bubbles which float to the surface to be separated. The final stage of separation is the skimming off of the surface froth which carries with it the mineral concentrate. The gangue minerals sink to the bottom of the tank.

Although plants are designed to obtain the maximum percentage recovery of the economic content of the ore, this recovery level rarely exceeds 95 percent and may be as low as 50 percent. The Ok Tedi gold-copper mine recovers between 30-40 percent per day using this technique.

7. Refining of economic minerals

How is the metal separated? Concentrates of a mineral are subjected to various processes to recover the chemical element in the required form. Although the various processes are broadly similar, there are normally some specific operations for each element.

Smelting

Smelting is a process which occurs when the ore and gangue minerals react at high temperatures with added components. The process produces two melts, a heavy metallic melt and a light silicate melt, which separate and can be tapped from different levels of the furnace. Oxide minerals of iron such as hematite or magnetite may be reduced directly in a blast furnace to metallic iron containing impurities such as silicon, manganese, carbon and sulphur.

In treating sulphide minerals such as galena or chalcopyrite, the concentrates may be roasted to remove sulphur. In the case galena all of the sulphur is removed producing *lead sinter*. For chalcopyrite, part of the sulphur is removed by the roasting. The sulphur oxides which result from roasting may be used to make sulfuric acid. The sintered lead concentrates are then smelted in special blast furnaces and the lead metal is further refined to remove impurities such as copper, antimony or arsenic before being desilverised, a process which recover gold and silver.

Roasted copper ores are smelted in units such as reverberatory furnaces to produce *mattes*, a combination of iron, copper, sulphur and impurities. The matte may be electrolytic refined to produce pure copper and to separate out gold, silver and possible platinoid group metals. These trace metals are then recovered by separate processes. In electrolytic processes, pure metal is deposited from solution by electric current.

Refining

Refining varies with metals. Gold serves to illustrate. The melt bars produced at mine site are transported to a gold refinery for final processing. Gold and silver are separated or refined into gold and silver bullion. The main methods of refining gold are:

(i) Miller Process – bubbling chlorine gas through molten metal. Most base metals are released as a chlorine gas while silver and some copper forms a liquid chloride layer which is skimmed off the surface.

(ii) Aqua Regia – dissolving the impure metal in a mixture of nitric and HCl acids (aqua regia). Silver is turned into silver chloride – insoluble and settles at bottom. Pure gold is precipitated from solution by sulphur dioxide. Remaining solution has all silver and gold removed and only contains traces of base metals.

(iii) Electro-refining – passing electric current through a gold solution in an electrolytic cell. Pure gold is deposited on cathode of cell, leaving impurities in solution or at bottom of cell.

After refining – gold is usually 99.9% or higher in purity. This is made into internationally tradeable 400 ounce bullion bars or one kilobars – most popular in SE Asian markets.

8. Transportation of minerals

Mineral ores – mined ore is either by trucked or sent through a conveyor belt system (e.g., the Hidden Valley mine) to the crushers. Then the ore is transported to the beneficiation plant for further processing. In some mines, the crushed ore is mixed with water (slurry) and piped to the coast for either further processing or for sale (e.g., Ok Tedi mine in Western Province) and Ramu mine in Madang.

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (notes, charts) on mineral exploration and mining and ask questions on the different techniques used in these processes. Teachers can take students out for an excursion to the nearest mine or quarry project (if possible).	Students will use the information provided to answer questions on mineral exploration, mining and refining.

STEAM Approach

Learning Objective: By the end of the topic, students will be able to;

- Visualise, compare and contrast techniques used in the exploration, mining and refining of minerals - STEAM

Teaching Strategies	**Learning Strategies**
Teachers will provide the information for students to read, observe and answer questions within a given period of time.	Students read the notes and use the materials available to understand the processes involved in mineral exploration, mining and refining.

Recommended Resources:

- Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p
- http://www.ispatguru.com/natural-gas-its-characteristics-and-safety-requirements/
- https://www.OilScams.org
- PNG OresomeResources.com – Minerals and Energy Education

Unit 1: Earth Resources

Content Standard	**12.2.1** Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.
Benchmark	**12.2.1.4** Examine and compare the exploration and extraction of oil and gas.

Topic 4: Exploration and Extraction of Oil and Gas

Learning Objectives:
By the end of this topic, the students will be able to:

- Describe the processes involved in the issuing of oil and gas exploration license
- Asses the different methods used in oil and gas exploration
- Describe the processes involved in oil and gas drilling, logging, reserve estimate and well completion
- Asses the different techniques used in oil and gas production, refining and transportation

Essential questions

1. What are the processes involved in the issuing of petroleum exploration licences?
2. What are some of the methods involved in petroleum exploration?
3. How crude oil and gas are explored, extracted and refined?
4. How are oil and gas and their refined products transported?

Vocabulary: Oil and gas exploration, drilling, logging, reserve estimate, well completion, production, refining

Concepts	Essential Skills	Essential Values and Attitudes
• Oil and gas exploration license • Oil and gas exploration • Drilling and logging • Reserve estimate and well completion • Production of oil and gas • Refining of crude oil	• Making generalisations • Analysing • Comparing and contrasting • Visualising • Reasoning	• Open-minded, with a desire to learn, optimistic, critical

Content Background

1. Permitting processes (licenses) and exploration for oil and gas

Petroleum permits

Like the mining sector, there are several legislative regimes applying to the exploration and production of petroleum in Papua New Guinea. Each regime differs in terminology and detail, but nevertheless reflects some commonly applicable general principles.

Unlike some other countries (such as the USA and Australia), all naturally occurring petroleum in the ground has been vested in the State. This emphasizes the ‘public’ ownership of all PNG petroleum resources with no private ownership of petroleum in-situ. Each applicable petroleum legislative regime provides for private participation and ownership in petroleum resources according to statutory rules by issuing titles with names such as authorities, permits, licences and leases.

By each relevant legislation, the relevant Minister on behalf of the State is usually empowered to exercise the State's right relating to petroleum and to regulate matters according to the applicable legislative rules. Petroleum titles are generally labelled exploration or development, reflecting the type of petroleum activity permitted under each. Exploration titles cover larger areas and are of shorter duration than development titles. Quite separately there are legislative provisions covering retention and pipeline licences.

In PNG both onshore and offshore permits can be granted. Such grants and dealings are usually recorded in the title documents themselves or otherwise registered by licensing authorities. Therefore it is customary for the legal titles to be held by the companies, whose names appear on the permit. Usually one of these companies will be appointed as operator for the consortium concerned and it carries out work programs and keeps the licensing authorities informed as required. The operator then accounts to participants in the joint venture for the total costs and benefits accruing.

Petroleum prospecting licence

For the duration of the permit, the holders virtually have an exclusive right to conduct exploratory activities in the permit area, including geophysical and geological surveys plus drilling and testing of exploration wells. However commercial production of any petroleum found is not permitted under an exploration permit.

Generally the results acquired are retained by the permit holder (for a period) as confidential. The titles are usually held on a joint and several basis when granted by the licensing authorities. However the companies concerned share the costs and benefits of each title on the basis of undivided shares.

Onshore, the duration of an exploration permit in PNG is two years, with other provisions applying relating to renewals and partial or progressive relinquishment of areas within the origin permit. Offshore, the duration of exploration is six years, with the right to renew up to half the permit for successive five-year terms.

All permits require compliance with applicable rules and regulations, including those relating to minimum safety specifications and other technical requirements, as well as the restoration of the permit area at the end of the permit's term. The permit holder is required to supply the relevant authority with the annual work programs for approval; quarterly and annual reports; daily drilling reports; and notification whenever petroleum is encountered whether it is found in commercial quantities or not.

The authority concerned has the capacity to waive, vary or grant, upon application, a deferment of work programs and/or relinquishment conditions for the permits. A bond or form of security in a prescribed form is generally required in respect of each permit.

The actual area encompassed by an exploration permit contains a certain number of graticular blocks. Each offshore block measures five minutes of latitude by five minutes of longitude. Onshore blocks are generally also bounded by parallels of latitude and meridians of longitude.

The method of application for exploration permits falls into two categories – direct application, and tender following gazettal.

(a) Direct application involves an eligible company or person applying for a permit to explore land that is not covered by an existing permit, and that is not the subject of intended government gazettal or excluded for some other reason such as national park land. The applicant submits an intended work program together with financial and technical bona fides and available technical advice.

The Minister reserves the right to grant or refuse the permit. In some cases the Minister may also elect to vary the size or shape of the area applied for and set minimum work conditions. The licence award is also subject to environmental consideration.

(b) Calls to interested parties to tender for gazette (publicly advertised) areas is generally made known through government or trade journals and notifies the industry of government intend to licence new permits. It also sets a time for explorers to consider the areas on offer and make applications. Again work programs must be submitted along with financial and technical bona fides and available technical advice.

In this instance the size of each permit is specified in the gazettal notice. For offshore exploration permits, gazettal is the only method of releasing new areas and there are two ways of making applications:

(i) A modified work program application must specify an exact program for each of the first three years of the permit duration as well as details of a secondary program in each of the final three years based on probabilities of success in the first half of the permit term. A clear distinction must be made between wildcat drilling and appraisal drilling and the first three year program must be completed if cancellation of the permit is to be avoided.
(ii) Cash bidding is a method that awards the permit to the highest bidder in cash terms, provided the relevant Minister is satisfied with the financial and technical abilities of the applicant. In this instance a work program is still submitted, but it is a secondary consideration and there is no obligation to complete it during the six-year licence period. However, there is no right of renewal after the six-year term expires.

Petroleum production licence

The holder of an exploration permit who has made a petroleum discovery has a statutory right to apply for, and upon satisfying other requirements, obtain a production licence in respect of the discovery. However, the legal right of an exploration permit holder to be entitled to a grant of production titles for petroleum remains subject to ministerial discretion. Nevertheless, in practice, the withholding of a production licence to such an applicant rarely occurs.

The major right afforded by a production licence is to produce and sell the petroleum discovered, which previously was the State's property, subject to the payment of a royalty. This payment if calculated according to a fixed percentage of the wellhead value of production.

The area of a production licence again is based on graticular blocks, but is much smaller than an exploration permit as it only covers the region immediately surrounding the discovery. The duration of a production licence is a fixed number of years with a provision for renewal as of right, other than those exceptional cases onshore where it still is a matter of ministerial discretion. Regulations governing working practices are specified and the relevant Minister or authority concerned requires details of production and development in the form of regular reports.

Petroleum retention licence

If a discovery is made which is not commercial at the time, but which may be viable in years to come, a permit holder may apply for a retention lease or licence which requires no or minimal work commitments. The retention lease is granted for a renewable five-year term at the discretion of the designated authority.

Oil and gas exploration

Oil and natural gas reserves are found in many parts of the world. In the past, demand was low and reserves were easy to find. In fact, the first users of oil depended on surface seepage for their supplies. However, as demand has increased, all the easy-to-find oil has been used. Today, oil exploration takes place in some of the most challenging places on earth. We are now looking for new oil reserves thousands of metres under the ocean and in areas of climatic extremes.

Oil and natural gas are formed when decaying plants and micro-organisms are trapped in layers of sediment and – over the course of millions of years – become buried deep within the earth, where underground heat and pressure turn them into useful hydrocarbons, such as oil and natural gas.
The layers of rock in which hydrocarbons are formed are called source rocks. High pressures underground tend to squeeze hydrocarbons out of source rocks into what are called *reservoir rocks*. These are rocks, such as sandstone, which feature pores large enough to permit fluids like oil, natural gas, and water to pass through them. Since oil and natural gas are less dense than water, they will float upward toward the surface. If nothing stops this migration, the oil and natural gas may reach daylight through what is called a surface seep.

More often, however, hydrocarbons' path upward is blocked by a layer of impermeable rock, such as shale, or by some other geologic formation. These trap the oil and natural gas, either in an underground pocket or in a layer of reservoir rock, so that it may be recovered only by drilling a well.

There isn't any way to be absolutely sure where new oil and natural gas reserves are located, so petroleum geologists and engineers need to collect clues as to what lies deep beneath the earth's surface. Advanced technology has revolutionized the exploration process for oil and natural gas, and helps them pinpoint potential reserves with greatly improved accuracy. This results in fewer wells, and lowered exploration costs.

Petroleum geologists can gather above-ground clues using airplanes and satellites to map the surface, to identify promising geological formations, and to look for oil and natural gas seeps. Ships can do the same for the ocean floor. But geologists often get much more useful information by looking at geological structures and rock properties below the surface. They use a number of strategies including:

Seismic surveys

Seismic surveys are done by sending high-energy sound waves into the ground and measuring how long they take to reflect back to the surface. Since sound travels at different speeds as it passes through different materials, computers can use seismic data to create a 3-D map of what lies below the surface.

Geologists and geophysicists use these 3-D seismic images to look for accumulations of oil and natural gas. Engineers then use the data to plan the safest, most cost-effective well path to the reservoir.
Once a reservoir has been located and put into production, a series of 3-D seismic surveys can be taken over time to see if all of the oil and natural gas reserves are being efficiently drained. If not, additional wells can be drilled to produce these bypassed pockets of reserves.

While seismic data are extremely useful to geologists, these surveys are also very expensive.

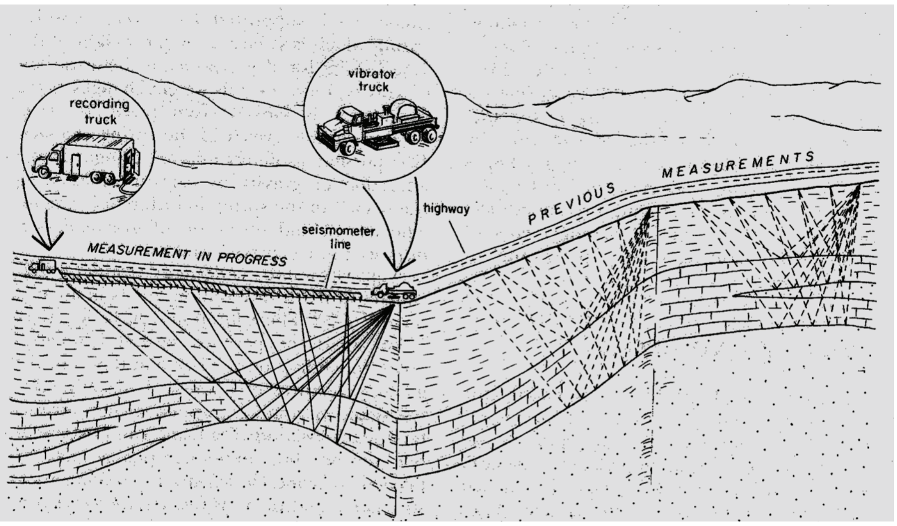


Figure 1. *Schematic diagram of the seismic reflection survey* (From Kearey et al., 2002).

Gravity and geomagnetic surveys

These relatively inexpensive techniques can identify potential oil and natural gas bearing sedimentary basins and structures. High-resolution aeromagnetic surveys done by special aircraft can also show fault traces and differentiate between different rock types near the surface.

2. Drilling and logging for oil and gas

Drilling exploration wells

When the data indicate a likely site for oil and natural gas reserves, an exploration well is often drilled. Rock samples from the well are brought to the surface and analysed. Well logs measure the electrical, magnetic and radioactive properties of the rocks.

By examining this information, a geologist can learn a great deal about the sub-surface structures and whether or not the site is likely to produce oil and natural gas in economic or *paying* quantities.

Drilling for oil and natural gas is a complex process, but advanced technology has made the job more efficient and productive while providing less impact on the environment.

Some people believe that oil and natural gas companies can explore for oil wherever they want. This is not true. Companies must secure permits (environmental, exploration licence) from relevant authorities.

The drilling rig

(a). The *drilling derrick* is used to position and support the drill string. Modern drilling equipment comes in a wide range of sizes. Many wells can be drilled with equipment that requires far less space than in the past.

(b). Drill rigs now run on electricity to supply the power to turn the bit and raise and lower the drill pipe and casing. Since most drilling occurs in remote areas, the electricity is supplied by electric power generators that run on diesel fuel. These generators make drilling rigs much quieter than in the past.

(c). The *drill bit* uses three conical shaped cutting surfaces to grind rock into rice-sized particles. The newest bits drill 150 percent to 200 percent faster than similar bits just a few years ago! The drill string consists of lengths of pipe fastened to each other and to the drill bit. The drill string transmits power from the top drive to the drill bit.

(d). As the drill cuts into the rock, drilling mud is added to the hole. This helps cool the drill bit, and the mud is circulated to bring cuttings to the surface. The weight of the *drilling mud* keeps the hole open. It also helps counteract the pressure of any gas or fluids encountered along the way, in this way preventing a well from loss of control or "blow out.”

Figure 2. *Drilling rig on the Karius Anticline (Hides), Papuan fold.* Photo courtesy of PNG Chamber of Mines and Petroleum.

(e). Protecting the aquifer from contamination is a major concern of the oil and natural gas industry. *Casing* made of steel or high-tech alloys is lowered into the hole and cemented into place to protect fresh water aquifers. The casing also keeps the hole open so that oil and natural gas can be brought to the surface.

(f). To reduce waste, the drilling mud is passed through a sieve where the ground rock particles or cuttings can be removed. Then the mud is recycled back into the hole.

(g). Dirt and rock cuttings are removed from the hole and temporarily stored nearby. Holding areas are carefully sited, lined and often times covered with nets to protect local wildlife.

(h). All aspects of the drilling operations are closely monitored to ensure efficient drilling and safety. Electronic sensors measure drilling rates, vibration, pressure, rock type, mud properties and many other drilling parameters. Computers monitor operations and collect data from inside the well. With advanced communications technology, drilling personnel can share and review this data with engineers and geologists located thousands of kilometres away. If a problem is detected, the rig can be safely and quickly shut down.

Well evaluation

Rock and fluid properties will determine how much oil and natural gas can be recovered from a reservoir. After an exploratory well has been drilled, it is evaluated to determine if there is enough oil and natural gas in the reservoir to make it economically feasible to initiate recovery operations.

Drill cuttings and core samples - As the drilling mud is brought to the surface, it is run through a sieve to remove the drill cuttings (pulverized rock) before the mud is recycled down into the well. Small pieces of rock are selected for microscopic analysis to determine the type of rock being drilled, how porous it is, and whether oil is present. The drilling mud also is analysed with sensors to see if trace amounts of oil or natural gas are present — an indication of a possible accumulation at depth. In the past, rock cuttings were the principal source of well information.

Well logging - A special bit can be used to cut a cylindrical piece of rock that can be brought to the surface for analysis. The core is sent to a laboratory where the exact porosity and permeability can be determined. This gives a good indication of how well oil or natural gas would flow through the rock. Fluid samples can be taken and analysed to determine the amount and type of hydrocarbon present in the rock.

Wells are completed for production if the value of the recoverable oil and/or natural gas is greater than the cost of drilling and producing them and delivering them to market. If not, the well is plugged In accordance with industry standards and federal or state requirements (depending on the location) and the site is restored.

In water depths of less than 100 metres, a Jack-up rig can be used. This type of rig has legs that support the rig from the sea floor. In depths where legs are impractical, Semi-submersible rigs and Drill Ships are used. These vessels float above the well and are designed for use in water depths up to 4000 metres.

These floating drilling rigs are complicated because of the movement of the rig caused by swells and tides. All offshore drilling rigs protect the marine environment by connecting a steel tube called a marine riser between the well and the rig.

3. Reserve estimate and well completion

Well completion

Preparing a well for production is a complex process. Each step in the process is shown in the following:

(a). A pipe, called the casing, is lowered down the drilled hole. Sections of casing fit together just like the drill pipe. Cement is then pumped through the bottom of the casing so that it fills the area between the casing and side of the well. The casing prevents oil, gas and deep brines (underground salt water) from entering and contaminating aquifers (underground fresh water).

(b). Because the casing and the liner must remain in a well for a long time and their repair or replacement would be costly, another string of pipe is placed in the well through which oil or gas is usually produced. This string of pipe is called "tubing". This is like a double-hulled tanker in that it provides an extra layer of protection for groundwater supplies. Tubing is pulled out of the hole on occasion and inspected to see if it needs to be repaired.

Detonating the charges forces holes in the casing. Fluids can then flow into the casing and up the tubing toward the surface.

(d). A "Christmas Tree" is a device that is placed on the well at the surface (Fig 9). It regulates the flow from the well into the pipelines that take the oil and natural gas to facilities for processing and sale. It consists of a series of valves that are opened and closed to regulate flow for optimum field production or to shut down a producing well if a problem is detected. Some Christmas Trees have computer systems that allow them to be monitored, opened and closed remotely.

Figure 3*. Well completion – "a Christmas tree"* (Source: www.westfieldenergy.com)

4. Extraction of crude oil and gas

Extracting oil and natural gas from deposits deep underground isn't as simple as just drilling and completing a well. Any number of factors in the underground environment – including the porosity of the rock and the viscosity of the deposit - can impede the free flow of product into the well. In the past, it was common to recover as little as 10 percent of the available oil in a reservoir, leaving the rest underground because the technology did not exist to bring the rest to the surface. Today, advanced technology allows production of about 60 percent of the available resources from a formation.

Primary recovery - first relies on underground pressure to drive fluids to the surface. When the pressure falls, artificial lift technologies, such as pumps, are used help bring more fluids to the surface. In some situations, natural gas is pumped back down the well underneath the oil. The gas expands, pushing the oil to the surface. Gas lift technology is often used in offshore facilities. Primary recovery often taps only 10 percent of the oil in a deposit.

Figure 4. *Oil production pump – “a nodding donkey”* (Source: www.greencarreports.com)

Secondary recovery - is the most widely applied enhanced recovery technique. Water that is produced and separated from the oil in the initial phase of drilling is injected back into the oil-bearing formation to bring more oil to the surface. In addition to boosting oil recovery, it also disposes of the waste water, putting it back where it came from. This can bring an additional 20 percent of the oil in place to the surface.

Enhanced recovery - techniques are used to mobilize the remaining oil. There are three common approaches: thermal recovery, gas injection or chemical flooding. ***Thermal*** recovery entails injecting steam into the formation. The heat from the steam makes the oil flow more easily, and the increased pressure forces it to the surface. ***Gas injection*** uses either miscible or immiscible gases. Miscible gasses dissolve CO_2, propane, methane or other gasses in the oil to lower its viscosity and increase flow. Immiscible gasses do not mix with the oil, but increase pressure in the “gas cap” in a reservoir to drive additional oil to the well bore. ***Chemical*** flooding involves mixing dense, water-soluble polymers with water and injecting the mixture into the field. The water pushes the oil out of the formation and into the well bore.

Enhanced recovery techniques are employed to bring as much as 60 percent of the reserve to the surface.

Wells are not just drilled vertically. Horizontal drilling is now common. The drill bit can be steered to drill across, rather than through reservoirs. This enables increased production from thin reservoirs. Fields which previously were considered too small to be economically viable, can now be tapped. Technology is always improving.

A large field may require two or three production platforms, with up to 20 production wells from each platform. Wells can be drilled to over 5000 metres below the sea-bed. Some reach as far as eight kilometres horizontally from the platform.

5. Refining crude oil

Petroleum refining processes are the chemical engineering processes and other facilities used in petroleum refineries (also referred to as oil refineries) to transform crude oil into useful products such as liquefied petroleum gas (LPG), gasoline or petrol, kerosene, jet fuel, diesel oil and fuel oils.

Petroleum refineries are very large industrial complexes that involve many different processing units and auxiliary facilities such as utility units and storage tanks. Each refinery has its own unique arrangement and combination of refining processes largely determined by the refinery location, desired products and economic considerations.

Figure 5. *An oil refinery* (Source: Africa Oil & Gas Report)

The major processes that take place in a refinery are:

Fractionation - Crude oil is separated into its various components in a fractionating column. The oil is passed into the base of the tower where the temperature is at its highest. The various fractions vaporise and rise up the column. The heaviest fractions with the highest boiling points such as lubricating oils, diesel oils and bitumen, condense low down in the tower and are extracted nearer the base.

Catalytic Cracking - Heavier less valuable parts of the oil mixture that come from the distillation plant are 'cracked'. Larger molecules are broken into smaller molecules using a catalyst (a substance which speeds up a process) of alumina silica. Today, catalysts can extract 80 percent of light oil from heavy crude. A few years ago only 40 percent would have been possible.

Purification - The removal of sulphur, oxygen, nitrogen, trace metals such as vanadium, silicon, sodium and other unwanted elements and compounds.

Blending - Many individual components are mixed together to produce finished products.

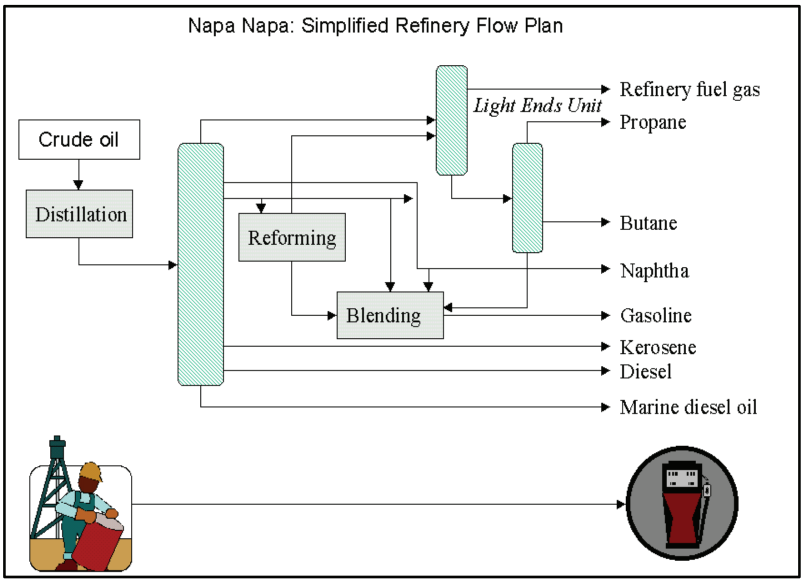


Figure 6. *Simplified flow plan of the Napa Napa oil refinery, Port Moresby.*

Refining end-products

The primary end-products produced in petroleum refining may be grouped into four categories: light distillates, middle distillates, heavy distillates and others.

Light distillates include C_1 and C_2 components, liquid petroleum gas (LPG), light naphtha, gasoline (petrol), and heavy naphtha. Middle distillates include kerosene, automotive and rail-road diesel fuels, residential heating fuel, and other light fuel oils. Heavy distillates are heavy fuel oils, wax, lubricating oils, and asphalt. Others include coke (similar to coal).

6. Transportation of oil and gas

Crude oil – produced crude oil is transported by road or railway to the refinery. Sea transport is by crude ship. Refined products are transported to their destinations in a similar fashion. Most refinery products are transported in containers – petrol in drums, gas in cylinders, etc.

Natural gas – produced gas is conditioned and piped to a processing plant for further processing. Normally it is liquefied and transported by specialised LNG cargo ships.

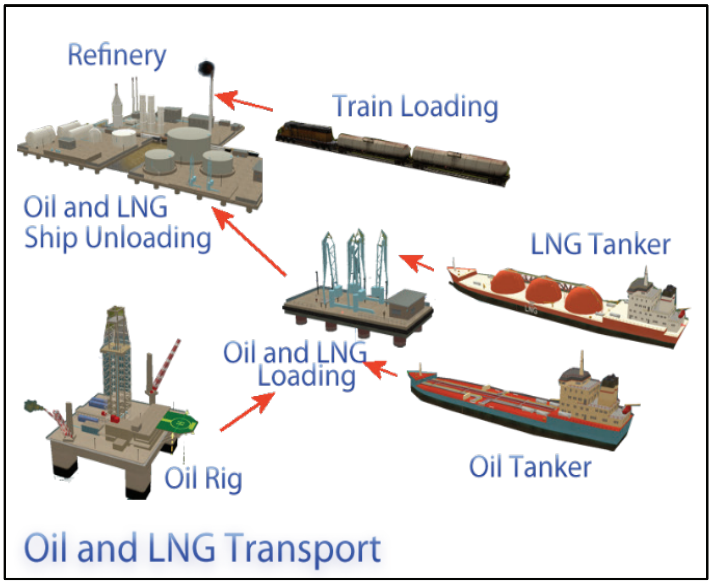


Figure 7. *Simplified diagram showing production platforms and transportation of oil and gas.*

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (notes, charts) on oil and gas exploration and production, and ask questions on the different techniques used in these processes. Teachers can take students out for an excursion to the nearest oilfield or petroleum project (if possible).	Students will use the information provided to answer questions on oil and gas exploration, production and refining.
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Visualise, compare and contrast oil and gas exploration, production and refining - STEAM	
Teaching Strategies Teachers will provide the information for students to read, observe and answer questions within a given period of time.	**Learning Strategies** Students read the notes and use the materials available to understand the different techniques involved in the exploration, production and refining of crude oil and gas.
Recommended Resources: • Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p • http://www.ispatguru.com/natural-gas-its-characteristics-and-safety-requirements/ • https://www.OilScams.org • PNG OresomeResources.com – Minerals and Energy Education	

Unit 1: Earth Resources

Content Standard	**12.2.1** Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.
Benchmark	**12.2.1.5** Explore and analyse the environmental regulations of mining activities set by the government.

Topic 5: Mining and the Environment

Learning Objectives:
By the end of this topic, the students will be able to:

- Describe the environmental regulations related to mineral and fossil fuel extraction and production
- Describe the different environmental policies on mining and fossil fuel extraction
- Describe mine closure plan and environment rehabilitation after mine closure

Essential questions

1. What are the regulations related to mineral, fossil fuel extraction and production?
2. What is an Environment Impact Statement?
3. What is a Mine Closure Plan?
4. What is environment rehabilitation?

Vocabulary: environment regulation, environment impact statement, mine closure, environment rehabilitation

Concepts	Essential Skills	Essential Values and Attitudes
• Oil and gas exploration license • Oil and gas exploration • Drilling and logging • Reserve estimate and well completion • Production of oil and gas • Refining of crude oil	• Making generalisations • Analysing • Comparing and contrasting • Visualising • Reasoning	• Open-minded, with a desire to learn, optimistic, critical

Content Background

1. Environmental regulations related to mineral, oil and gas extraction and production

What environmental regulations are in place? Mining provides us with minerals, metals and other materials we use every day and these minerals have economic value and can benefit mankind. In PNG mining development has impacted less than 1% of the total landmass. However, depending on the size of the mine, method of mining and location, mining can have a significant impact on the local environment. To minimise the effects of this impact, careful planning, management and supervision are required.

In Papua New Guinea, mining operators must follow strict regulations to protect the environment. These regulations were put in place in the year 2000 by the National Government Department of Environment and Conservation (DEC) and is known as the Papua New Guinea Environmental Act, 2000. These laws not only regulate land use, but also include regulation over clean air, noise reduction, management of waterways, fauna and flora and community socio-economic impacts.

All exploration activities must be carried out in a responsible manner to avoid harm to the environment. Companies pay a security deposit to satisfy licence requirements and are required to complete rehabilitation of areas disturbed during exploration.

Before permission to mine is granted, mining companies must submit to the Government, detailed reports explaining the project, the areas to be disturbed and the expected impact on the land, water, air, plants, animals and the community. The DEC will then decide if the project is classed as a minor or major project according to the size of its impact. If the project is classed as minor, then an environmental licence can be issued. However, if it is a major project then the company will need to complete an Environmental Impact Statement (EIS), which is a formal document clearly describing the positive and negative environmental effects of a proposed action.

Alluvial gold mining is very common in PNG with an estimated 60,000 persons actively involved in alluvial mining. Persons performing alluvial mining using any machine must apply for an Alluvial Mining Lease (AML). Granting of an AML will require persons to also follow various environmental conditions.

Environmental monitoring

What environmental monitoring is done? The mining company will be required to develop an Environmental Management Plan (EMP) that will contain details on the different types of monitoring mechanisms, how often the monitoring will be done and reporting of the results. Each mine has to write an annual monitoring report and submit it to the Department of Environment and Conservation. The mines employ specialist environmental scientists including water chemists, biologists, hydrologists and other technicians who manage these programs.

Monitoring programs typically collect samples of water (fresh and marine surface water and groundwater), soil, waste rock and tailings, air (dust, fumes), plants and animals. The samples are tested and compared to PNG standards or levels set in the mine EMP licence.

The oil industry and environmental issues and controls

The oil industry has been acutely aware of environmental issues for many years. The industry in the 1990s is aware of the need to pay close attention to environmental matters in its operations. An increasing amount of detailed research and data collation is carried out to produce environmental impact statements prior to any oil or gas program or project ahead, onshore or offshore.

Then there is a continual monitoring of systems and procedures during the exploration, appraisal and construction phases as well as during the project's working life. And looking even further ahead, there is detailed consideration given to removal of exploration or production equipment, and to restoration of sites once fields have been depleted. A number of companies go further still by actively funding or sponsoring wildlife research and conservation programs.

In most cases the petroleum industry sets far more stringent environmental controls on its own operations than are called for in Government regulations or legislation. Exhaustive toxicological tests are carried out before any substance or material is used. The ability of the petroleum industry to operate without polluting the ecosystem surrounding oil facilities is demonstrated particularly in marine regions where production platforms, even during construction, are havens for fish and other forms of marine life. The following examples illustrate the petroleum industry's moves to ensure there is no contamination and minimal disturbance to the environment.

Drilling fluids – All muds are ecologically tested to ensure there are no toxic effects on the surrounding environment. This involves extensive laboratory work as well as studies of natural reef, sea-bed and shoreline conditions in areas where drilling is to take place.

The first choice in designing a drilling program is to use a simple water-clay mix or a generic mud system which incorporates naturally occurring chemicals such as potassium chloride. Biocides and oil-based muds are only used in special circumstances. Where down-hole difficulties do require their use, stringent controls are employed to ensure minimal discharge and coatings of cuttings.

Waste disposal – Regulations governing the chemical and heavy metal content of waste material are strictly followed to and often surpassed, particularly in offshore locations. Onshore sullage ponds, flare and mud pits are efficiently lined so that pollutants have no chance of entering the natural ground water system. Toxic wastes are put into containers and sent to appropriate disposal units. All pits are filled in after use and the area restored.

Land care – Vegetation clearance for tracks or drilling sites is kept to a minimum to avoid erosion and to allow speedy re-vegetation. Instead of cutting through the topsoil to make tracks, many seismic lines are now rolled so that vegetation 'spring back' once the seismic vehicles have passed. Seismic lines are also diverted around large trees and bushes.

Blocking or diverting natural drainage patterns by building raised roads or pipeline easements is avoided and water courses are approached and departed from a 45o angle to prevent erosion and washout of stream banks. Burial of pipelines onshore and lines crossing inshore tidal zones is common practice.

Restorations of sites after use, including re-contouring to the natural line and re-sowing natural vegetation is common practice. The industry also pays special attention near sensitive areas such as mangroves, coral reefs, fauna breeding grounds and heritage areas.

Flare stack control – Where flaring of off-gases is required, new generation flare tips, now installed on a number of production installations, use the rush of gas to such air into the flare burner and create more complete combustion. There is also less smoke and less heat radiation produced than from a conventional flare.

Heritage sites - Petroleum companies make sure there is liaison with relevant landowners or landowner groups before any exploration or development programs begin. In many cases a close working relationship is built up. Landowner communities are consulted and actively involved before each step of a program so that there is ample time to relocate seismic lines and drill holes, if necessary, to avoid any sites of significance in a region.

Safety and monitoring systems - There is continual monitoring, inspection and maintenance program for all oil installations including offshore platforms, under sea pipelines and well heads to ensure integrity of structures is preserved. Sophisticated alarm systems are included in all oil facilities, such that operations can be shut down within seconds (by remote control from shore if necessary) in the event of a malfunction of equipment or an accident.

Oil spill control - An oil spill is the release of a liquid petroleum hydrocarbon into the environment (Fig. 1), especially marine areas, due to human activity, and is a form of pollution. The term is usually applied to marine oil spills, where oil is released into the ocean or coastal waters, but spills may also occur on land. Oil spills may be due to releases of crude oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil.

Figure 1. *Gulf of Mexico oil spill* (Source: Boston.com).

Oil spills penetrate into the structure of the plumage of birds and the fur of mammals, reducing its insulating ability, and making them more vulnerable to temperature fluctuations and much less buoyant in the water. Clean-up and recovery from an oil spill is difficult and depends upon many factors, including the type of oil spilled, the temperature of the water (affecting evaporation and biodegradation), and the types of shorelines and beaches involved. Spills may take weeks, months or even years to clean up.

Oil spills can have disastrous consequences for society; economically, environmentally, and socially. As a result, oil spill accidents have initiated intense media attention and political uproar, bringing many together in a political struggle concerning government response to oil spills and what actions can best prevent them from happening. Despite substantial national and international policy improvements on preventing oil spills adopted in recent decades, large oil spills keep occurring.

Offshore oil spill prevention and response can include:

- Secondary containment - methods to prevent releases of oil or hydrocarbons into environment.
- Oil Spill Prevention Containment and Countermeasures program by the United States Environmental Protection Agency.
- Double-hulling - build double hulls into vessels, which reduces the risk and severity of a spill in case of a collision or grounding. Existing single-hull vessels can also be rebuilt to have a double hull.
- Thick-hulled railroad transport tanks.

Spill response procedures should include elements such as:
- A listing of appropriate protective clothing, safety equipment, and clean-up materials required for spill clean-up (gloves, respirators, etc.) and an explanation of their proper use;
- Appropriate evacuation zones and procedures;
- Availability of fire suppression equipment;
- Disposal containers for spill clean-up materials; and
- The first aid procedures that might be required.

2. Environment Impact Statement

What is an environmental impact statement? The EIS requires mining companies to complete comprehensive baseline studies on the environment before it is affected by mine development and the planning thereof. These studies provide a baseline from which any future disturbance by a mine can be measured off. This process could take 1-2 years depending upon the size and complexity of the planned new mine.

The next step is to describe the impacts when the mine is developed to the environment. For example; land and forest clearing, development of an open pit, construction of waste rock dumps and tailings storage facilities, building of a processing plant, maintenance workshops, houses, airports, roads and impacts on the local communities. The social impacts include disturbances to cultural places, loss of gardens, effects on water supplies and village resettlement.

The EIS report must describe how these impacts are to be managed, what compensation is to be paid and also show the economic and social benefits that will flow to the community and various levels of Government including taxes, employment, education and resettlement plans. Details of overview mine closure and land rehabilitation must also be included in the EIS.

During the EIS studies the mining company is required to organise community meetings and consultation with the various Government authorities including Local Level, Provincial and National Government, to explain the project, its impacts and also the benefits. The outcome of these meetings will guide the Government. If there is strong opposition by the community to the project progressing, then further meetings and negotiations will be required to sort out the problem issues.

If the community gives consent or approval for the Project to start, then the Environment Council will recommend that the project can proceed and the PNG Government should approve the EIS. Only then can the company commence building the new mine.

3. Policies on environmental management of mining activities

Mining environmental impacts management

How are mining environmental impacts managed? The operating of a mine can have significant challenges in relation to land disturbance, impact on biodiversity (plants and animals), waste and recycling, use of water and energy use and emissions. This table outlines potential impacts and ways to reduce the impact.

Mining Environmental Impact	**Steps taken to reduce Impacts**
Animal and plant habitats are cleared.	Disturbed areas are rehabilitated or new habitats developed in line with the needs of local animal and plant species.
Houses, village gardens and crops are required for mine development.	Compensation payment. Relocation land to establish new resettlement houses and gardens.
The land is changed significantly as a result of open-cut mining.	Top soil is removed and reused later in rehabilitation. Land forms are re-contoured to resemble the natural landscape or shaped for other purposes determined by the local community e.g. gardens.
Large pits are created from open-cut mining.	Pits can be filled in with waste rock, used as storage areas for water or other uses following consultation with the local community.
Waste rock is generated from mining.	Waste rock is stored in engineered waste rock dumps, which are later reshaped, covered with topsoil and re-vegetated.
Underground mining can cause land subsidence.	In hard rock mining underground areas are backfilled with waste from the mining operations to minimise subsidence.
Waste from minerals processing is stored in tailings dams.	Tailings dams can eventually be covered with rock, clay and topsoil and then revegetated. Monitoring of the tailings occurs post mining.
Dust is emitted from tailings dams, open-cut mine stockpiles and trucks carrying ore.	Water trucks use recycled water whenever possible on mine sites to control the dust.
Noise from plant and equipment.	Installation of noise barriers, mufflers on noisy equipment.
Water is used in the processing of minerals and dust control.	Water is recycled wherever possible with excess water contained in dams or treated and released to the environment.
Vehicles and processing plant or power generation on mine site emit greenhouse gas emissions.	Vehicles with more efficient engines or larger trucks that carry more ore per tonne of emission. Electric shovels use less energy per tonne of ore moved compared to diesel powered shovels or loaders. Electric conveyor systems moving ore from the pit can be used instead of trucks. Poor road design and maintenance can impact fuel use.

***Source:** PNG OresomeResources.com - Minerals and Energy Education*

4. Environment management plan

How are tailings managed? Other operating mines in PNG discharge treated tailings to either the river environment (Ok Tedi, Porgera and Tolukuma gold mines) or as Deep Sea Tailings Placement (Lihir and Simberi gold mines and Ramu NiCo) from a long pipe into an ocean ravine where the tailings settle onto the deep ocean sea bed. All of these mines completed environmental studies on the impacts and are licensed by the PNG Government to discharge tailings in this way. Both riverine and deep sea tailings discharge is controversial as it results in the sediment smothering the river bed and ocean floor impacting on fish and other animals. This method of tailings discharge is not allowed in many other countries.

Tailings are one of the major waste products generated from mining projects that include a mineral processing plant which extracts metals from the ore on site. Tailings comprise finely ground up rock, containing chemicals, water and residues. Tailings can be potentially toxic and a threat to the environment. Tailings are usually stored in large earth wall dams where the sediment settles to the bottom of the dam and the water is reused in the processing plant. In places where there is high rainfall and excess water, the tailings water may be treated and discharged to the environment under strict environmental conditions. There is one operating tailings dam in PNG at the Hidden Valley gold mine.

5. Mine closure plan

What is mine closure planning? Planning for mine closure and rehabilitation of disturbed areas takes place before the mine is constructed. A Mine Closure Plan is required as part of the EIS planning documents. A mine closure plan will develop a conceptual model with drawings as to how the mine will look when operating and also when it is fully rehabilitated after closing.

The Plan will consider factors such as rainfall, winds, temperature ranges, pre-existing vegetation, ground water quality, soil conditions, topography, native flora and fauna when rehabilitation plans and activities are developed. The plan will consider disturbance, including open pit voids, waste rock dumps, tailings dams and other structures that will be left behind when the mine closes and will require rehabilitation.

Good practice mine closure principles state the site must be left in a safe and stable condition, re-vegetation must use local plants or crops and an agreement must be reached as to what the post mine land use will be (usually negotiated with the original landowners).

6. Environment rehabilitation

What happens after mining? In open-cut mining operations, rehabilitation can occur while mining takes place (Fig. 2). Top soil is stripped and stockpiled prior to mining for later use over rehabilitated areas. As mining ceases in one area, bulldozers and scrapers are used to reshape the disturbed area. Water drainage is designed to make the new land surface as stable as possible. Dams can be built to protect the area further from erosion and act as a permanent water storage area. The final contours of the land forms are smoothed and planted with trees, grasses or crops.

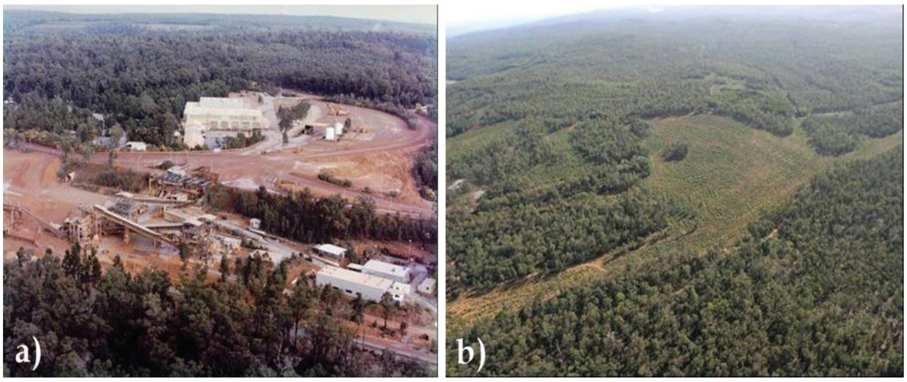


Figure 2. *An example of land rehabilitation after mining.*
(a) During mining, (b) Land re-vegetated after mining.

The type of rehabilitation of the mine site is determined in consultation with local community groups and takes into consideration the location and prior use of the land. Post mining land could be used for growing of gardens and crops, recreational use, the development of nature reserves or a new industry use such as forestry.

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (notes, charts, copies of the environment regulations and policies) and ask questions on the importance of these regulations and policies in relation to minerals, crude oil and natural gas extraction and development. Teachers can take students out for an excursion to the nearest mine or oil and gas project (if possible).	Students will use the information provided to answer questions on the importance of environmental regulations and policies on the extraction and development of minerals, crude oil, and natural gas.
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Visualise, compare environment regulations and policies - STEAM	
Teaching Strategies Teachers will provide the information for students to read, observe and answer questions within a given period of time.	**Learning Strategies** Students read the notes and use the materials available to understand the difference between environmental regulations and policies.
Recommended Resources: • Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p • http://www.ispatguru.com/natural-gas-its-characteristics-and-safety-requirements/ • https://www.OilScams.org • Internet • PNG OresomeResources.com – Minerals and Energy Education	

Unit 2: Age Data

Content Standard	**12.2.2** Students will be able to assess the significance of age dating including relative and absolute dating techniques.
Benchmark	**12.2.2.1** Analyse the age dating techniques.

Topic 1: Age Dating

Learning Objectives:

By the end of this topic, the students will be able to:

- Compare and contrast the relative and absolute age dating methods.
- Understand and explain the Venn diagram.
- Explain the radiometric (absolute) dating process.

Essential questions

1. What are essential aspects of relative dating?
2. What are essential aspects of absolute dating?
3. How do we understand an absolute dating process?

Vocabulary:
Relative age dating, uniformitarianism, superposition, faunal succession

Concepts	Essential Skills	Essential Values and Attitudes
• Relative • Absolute age dating • Venn diagram	• Making generalisations • Reasoning • Comparing and Contrasting	Open-minded, with a desire to learn, optimistic

Content Background

1. Numeric time and geologic time

Numeric (absolute) dating is the process of determining an age on a specified chronology in archaeology and geology. Some scientists prefer the terms chronometric or calendar dating, as use of the word "absolute" implies an unwarranted certainty of accuracy. Absolute dating provides a numerical age or range in contrast with relative dating which places events in order without any measure of the age between events.

In archaeology, absolute dating is usually based on the physical, chemical, and life properties of the materials of artefacts, buildings, or other items that have been modified by humans and by historical associations with materials with known dates (coins and written history). Techniques include tree rings in timbers, radiocarbon dating of wood or bones, and trapped-charge dating methods such as thermo-luminescence dating of glazed ceramics. Coins found in excavations may have their production date written on them, or there may be written records describing the coin and when it was used, allowing the site to be associated with a particular calendar year.

In historical geology, the primary methods of absolute dating involve using the radioactive decay of elements trapped in rocks or minerals, including isotope systems from very young (radiocarbon dating with ^{14}C) to systems such as uranium-lead dating that allow acquisition of absolute ages for some of the oldest rocks on earth.

Although both relative and absolute dating methods are used to estimate the age of historical remains, the results produced by both these techniques for the same sample may be ambiguous.

Geological specimens that are unearthed need to be assigned an appropriate age. To find their age, two major geological dating methods are used. These are called *relative and absolute dating techniques*. Absolute dating, also called *numerical dating*, arranges the historical remains in order of their ages. Whereas, relative dating arranges them in the geological order of their formation.

2. Relative dating

- It determines if an object/event is younger or older than another object/event from history.
- Relative dating is qualitative.
- This technique helps determine the relative age of the remains.
- It is less specific than absolute dating.
- Relative dating is comparatively less expensive and time-efficient.
- It works best for sedimentary rocks having layered arrangement of sediments.

The following are the major methods of relative dating.

Stratigraphy: The oldest dating method which studies the successive placement of layers. It is based on the concept that the lowest layer is the oldest and the topmost layer is the youngest.

Biostratigraphy: An extended version of stratigraphy where the faunal deposits are used to establish dating. Faunal deposits include remains and fossils of dead animals.

Cross dating: This method compares the age of remains or fossils found in a layer with the ones found in other layers. The comparison helps establish the relative age of these remains.

Fluorine dating: Bones from fossils absorb fluorine from the groundwater. The amount of fluorine absorbed indicates how long the fossil has been buried in the sediments.

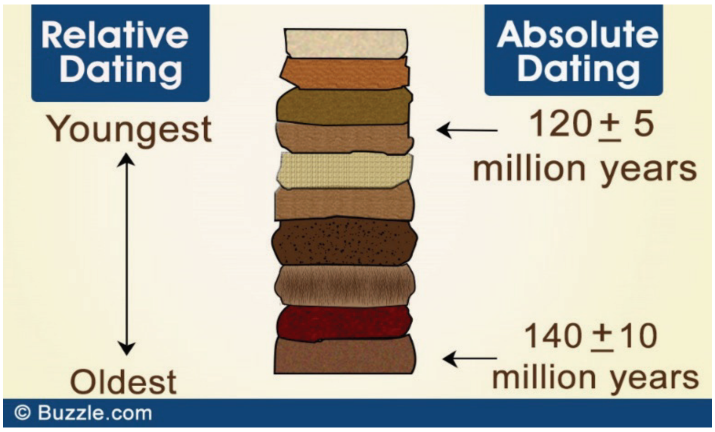


Figure 1. *Relative versus absolute dating* (Source: Buzzle.com)

3. Absolute dating

- It determines the age of a rock/object using radiometric techniques.
- Absolute dating is quantitative.
- This technique helps determine the exact age of the remains.
- It is more specific than relative dating.
- Absolute dating is expensive and time-consuming.
- It works best for igneous and metamorphic rocks.

The following are the major methods of relative dating.

Radiometric dating: This technique solely depends on the traces of radioactive isotopes found in fossils. The rate of decay of these elements helps determine their age, and in turn the age of the rocks.

Amino acid dating: Physical structure of living beings depends on the protein content in their bodies. The changes in this content help determine the relative age of these fossils.

Dendrochronology: Each tree has growth rings in its trunk. This technique dates the time period during which these rings were formed.

Thermo luminescence: It determines the period during which certain object was last subjected to heat. It is based on the concept that heated objects absorb light, and emit electrons. The emissions are measured to compute the age.

4. Comparison of dating methods using a Venn diagram

A Venn diagram depicts both dating methods as two individual sets. The area of intersection of both sets depicts the functions common to both. Take a look at the diagram to understand their common functions.

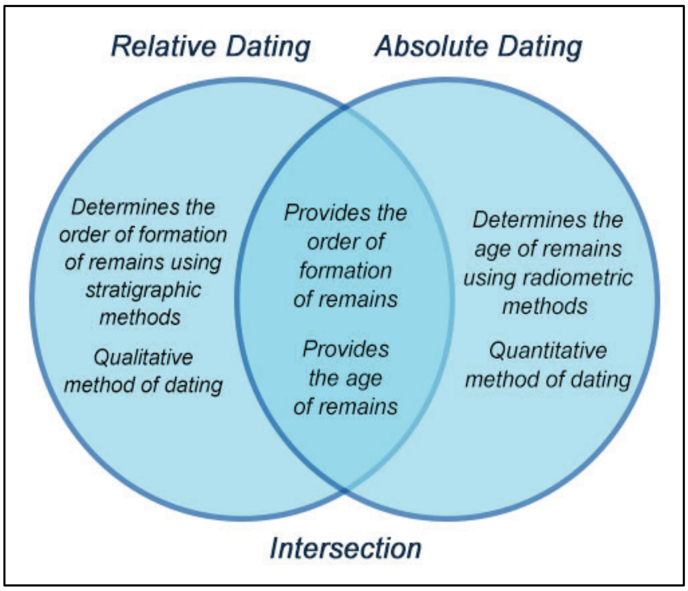


Figure 2. *Venn diagram*

When we observe the intersection in this diagram depicting these two dating techniques, we can conclude that they both have two things in common:

(a) Provide an idea of the sequence in which events have occurred.
(b) Determine the age of fossils, rocks, or ancient monuments.

Although absolute dating methods determine the accurate age compared to the relative methods, both are good in their own ways.

5. Radiometric methods

The problems of dating unfossiliferous and fossiliferous rocks has been resolved within the last 60 years by the development of dating methods based on the rate of decay of unstable isotopes of various elements, notably uranium, thorium, samarium, strontium, potassium and carbon.

Radiometric dating is based on the known and constant rate of decay of radioactive isotopes into their radiogenic daughter isotopes. Particular isotopes are suitable for different applications due to the types of atoms present in the mineral or other material and its approximate age. For example, techniques based on isotopes with half lives in the thousands of years, such as carbon-14, cannot be used to date materials that have ages on the order of billions of years, as the detectable amounts of the radioactive atoms and their decayed daughter isotopes will be too small to measure within the uncertainty of the instruments.

Radiocarbon dating

One of the most widely used and well-known absolute dating techniques is carbon-14 (or radiocarbon) dating, which is used to date organic remains. This is a radiometric technique since it is based on radioactive decay. Cosmic radiation entering the earth's atmosphere produces carbon-14, and plants take in carbon-14 as they fix carbon dioxide. Carbon-14 moves up the food chain as animals eat plants and as predators eat other animals. With death, the uptake of carbon-14 stops.

It takes 5,730 years for half the carbon-14 to change to nitrogen; this is the half-life of carbon-14. After another 5,730 years only one-quarter of the original carbon-14 will remain. After yet another 5,730 years only one-eighth will be left.

By measuring the carbon-14 in organic material, scientists can determine the date of death of the organic matter in an artefact or ecofact.

Potassium-argon dating

Other radiometric dating techniques are available for earlier periods. One of the most widely used is potassium–argon dating (K–Ar dating). Potassium-40 is a radioactive isotope of potassium that decays into argon-40. The half-life of potassium-40 is 1.3 billion years, far longer than that of carbon-14, allowing much older samples to be dated. Potassium is common in rocks and minerals, allowing many samples of geochronological or archaeological interest to be dated.

Argon, a noble gas, is not commonly incorporated into such samples except when produced in situ through radioactive decay. The date measured reveals the last time that the object was heated past the closure temperature at which the trapped argon can escape the lattice. K–Ar dating was used to calibrate the geomagnetic polarity time scale.

These methods were based on the fact that each unstable isotope has a characteristic decay rate. If we can determine what was the initial quantity (parent) of the unstable isotope in a sample of rock, and the present-day quantity of the daughter product in the same sample, and we know the rate of decay, then it is possible to calculate the age of the rock.

The decay rate of any unstable isotope is defined in terms of its half-life. The half-life is the time taken for the initial number of atoms of the unstable isotope to be reduced by one half (Fig 4). To determine the age of Precambrian rock we would use an unstable isotope that has a long half-life, such as ^{238}U, ^{235}U, ^{232}Th or ^{247}Sm. To determine the age of Phanerozoic rock we select an unstable isotope with a shorter half-life. The isotopes most commonly used for dating in the relatively young Southwest Pacific countries are ^{40}K and ^{87}Sr. A shorter-lived isotope, ^{14}C is used for dating archaeological sites with ages of less than 50,000 years. (Carbon-14 comprises 6 protons and 8 neutrons. It breaks down to form nitrogen-14, 7 protons and 7 neutrons, and releases one beta particle).

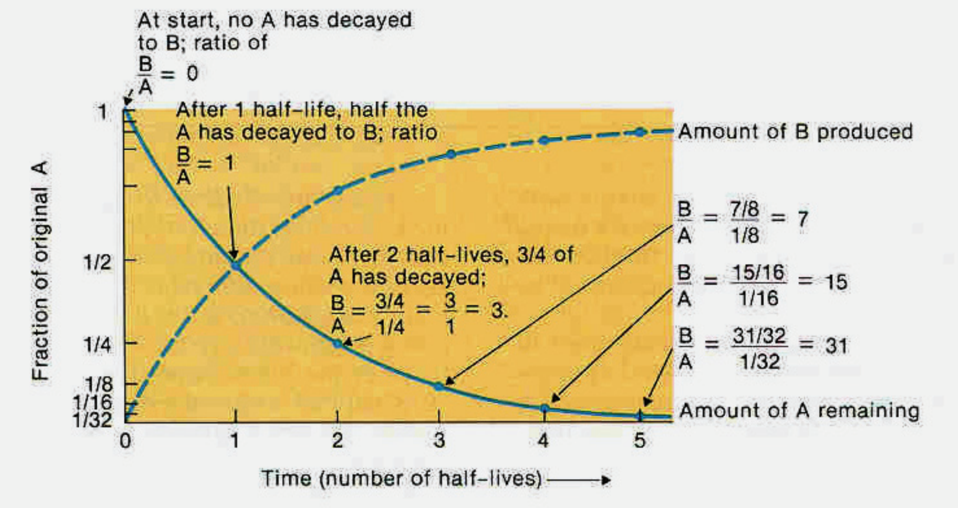


***Figure 3.** The measuring of time using the decay rate (after HL Davies, 2013).*

Unstable isotopes commonly used for age determinations are listed in the table below together with their half-lives and daughter products.

Parent isotope	Half-life (years)	Daughter isotopes
Potassium-40	1.3 billion	Argon-40
Rubidium-87	48.8 billion	Strontium-87
Thorium-232	1 4 illion	Lead-208
Uranium-235	70 4 million	Lead-207
Uranium-238	4.5 billion	Lead-207
Carbon-14	5,730	Nitrogen-14

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (notes, photos, charts) and ask questions on relative and absolute age dating methods. Teachers can take students out for an excursion to the nearest road to observe a road-cut geologic section.	Students will use the information provided to answer questions on relative and absolute age dating method.

STEAM Approach

Learning Objective: By the end of the topic, students will be able to;

- Visualise, compare relative and absolute age dating methods - STEAM

Teaching Strategies	**Learning Strategies**
Teachers will provide the information for students to read, observe and answer questions within a given period of time.	Students read the notes and use the materials available to understand the difference between relative and absolute age dating methods.

Recommended Resources:

- Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p
- https://sciencestruck.com/relative-vs-absolute-dating
- https://buzzle.com
- Internet

Unit 2: Age Dating

Content Standard	**12.2.2** Students will be able to assess the significance of age dating including relative and absolute dating techniques.
Benchmark	**12.2.2.2** Explore the principles of stratigraphy.

Topic 2 : Principles of Stratigraphy

Learning Objectives:
By the end of this topic, the students will be able to:

- Compare and contrast the different relative age dating methods.
- Understand and explain the principles of superposition.
- Explain the faunal succession in relation to age dating.

Essential questions

1. What are essential aspects of relative dating?
2. What are the stratigraphic principles in age dating?
3. What is faunal succession in relation to age dating?

Vocabulary: Relative age dating, uniformitarianism, superposition, faunal succession

Concepts	Essential Skills	Essential Values and Attitudes
• Relative age dating • Principles of stratigraphy	• Making generalisations • Reasoning • comparing and contrasting	Open-minded, with a desire to learn, optimistic

Content Background

1. Principles of stratigraphy 1

Methods for relative dating were developed when geology first emerged as a natural science in the 18th century. Geologists still use the following principles today as a means to provide information about geologic history and the timing of geologic events. The main principles (also called *laws*) are uniformitarianism, intrusive relationships, cross-cutting relationships, inclusions and components, original horizontality, superposition, faunal succession, lateral continuity, inclusions of igneous rocks, and included fragments.

Uniformitarianism

The principle of Uniformitarianism states that the geologic processes observed in operation that modify the Earth's crust at present have worked in much the same way over geologic time (Fig. 1). A fundamental principle of geology advanced by the 18th century Scottish physician and geologist James Hutton, is that "the present is the key to the past." In Hutton's words: "the past history of our globe must be explained by what can be seen to be happening now."

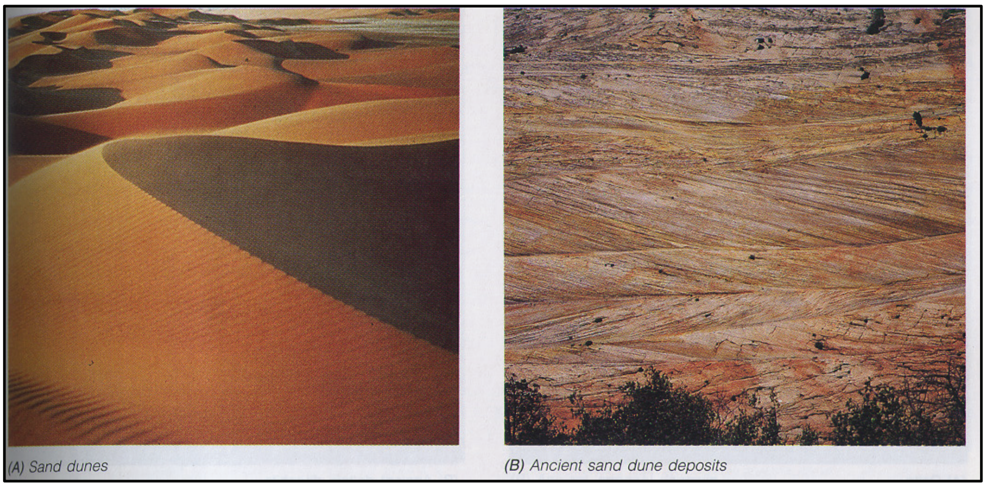


***Figure 1.** The Principle of Uniformitarianism. A – modern sand dunes, B – Ancient sand dunes.*

Intrusive relationships

The principle of intrusive relationships concerns cross-cutting intrusions. In geology, when an igneous intrusion cuts across a formation of sedimentary rock, it can be determined that the igneous intrusion is younger than the sedimentary rock. There are a number of different types of intrusions, including stocks, laccoliths, lopoliths, batholiths, sills and dikes. The principle of intrusive relationships concerns cross-cutting intrusions (Fig. 2).

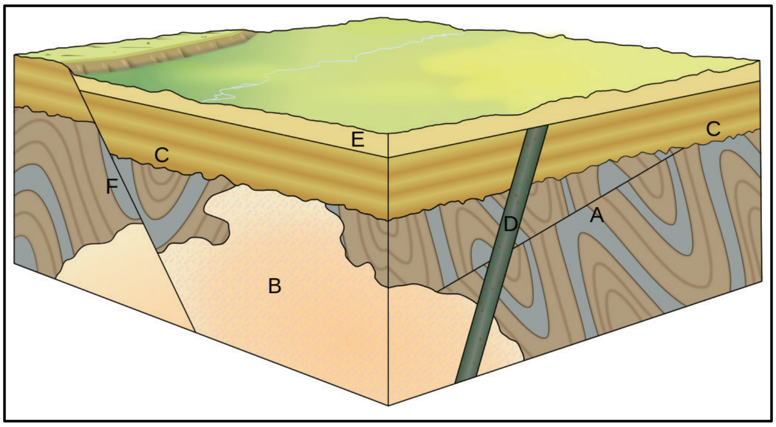


***Figure 2.** Cross-cutting relations can be used to determine the relative ages of rock strata and other geological structures. Explanations: A – folded rock strata cut by a thrust fault; B – large intrusion (cutting through A); C – erosional angular unconformity (cutting off A & B) on which rock strata were deposited; D – volcanic dyke (cutting through A, B & C); E – even younger rock strata (overlying C & D); F – normal fault (cutting through A, B, C & E).*

Cross-cutting relationships

The principle of cross-cutting relationships pertains to the formation of faults and the age of the sequences through which they cut (Fig. 2). Faults are younger than the rocks they cut; accordingly, if a fault is found that penetrates some formations but not those on top of it, then the formations that were cut are older than the fault, and the ones that are not cut must be younger than the fault. Finding the key bed in these situations may help determine whether the fault is a normal fault or a thrust fault.

Inclusions and components

The principle of inclusions and components explains that, with sedimentary rocks, if inclusions (or clasts) are found in a formation, then the inclusions must be older than the formation that contains them (Fig. 3). For example, in sedimentary rocks, it is common for gravel from an older formation to be ripped up and included in a newer layer. A similar situation with igneous rocks occurs when xenoliths are found. These foreign bodies are picked up as magma or lava flows, and are incorporated, later to cool in the matrix. As a result, xenoliths are older than the rock which contains them.

Original horizontality

The principle of original horizontality states that the deposition of sediments occurs as essentially horizontal beds. Observation of modern marine and non-marine sediments in a wide variety of environments supports this generalization (although cross-bedding is inclined, the overall orientation of cross-bedded units is horizontal).

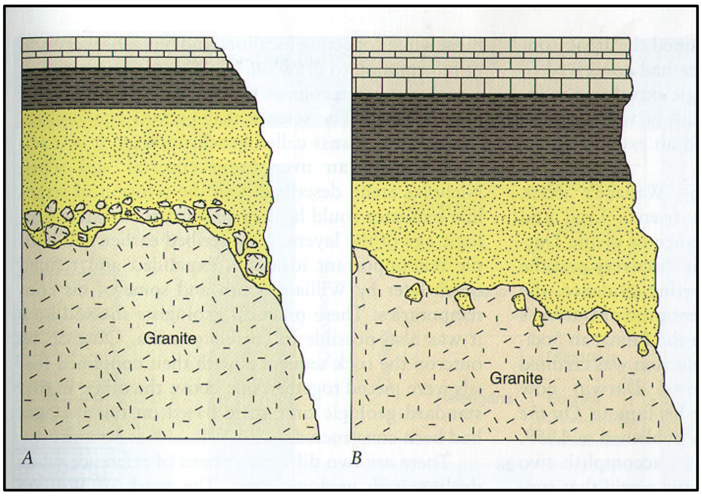


***Figure 3**. The principle of inclusions and components. A – Granite older. B – Sandstone older.*

Superposition

The law of superposition states that a sedimentary rock layer in a tectonically undisturbed sequence is younger than the one beneath it and older than the one above it (Fig. 4). This is because it is not possible for a younger layer to slip beneath a layer previously deposited. The only disturbance that the layers experience is bioturbation, in which animals and/or plants move things in the layers. However, this process is not enough to allow the layers to change their positions. This principle allows sedimentary layers to be viewed as a form of vertical time line, a partial or complete record of the time elapsed from deposition of the lowest layer to deposition of the highest bed.

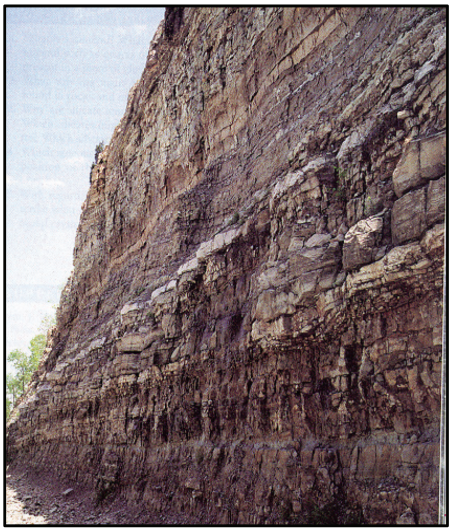


Figure 4. *Principle of superposition. Rock sequences are younging upwards (bottom to top).*

Lateral continuity

The principle of lateral continuity states that layers of sediment initially extend laterally in all directions; in other words, they are laterally continuous (Fig. 5). As a result, rocks that are otherwise similar, but are now separated by a valley or other erosional feature, can be assumed to be originally continuous.

Layers of sediment do not extend indefinitely; rather, the limits can be recognized and are controlled by the amount and type of sediment available and the size and shape of the sedimentary basin. Sediment will continue to be transported to an area and it will eventually be deposited. However, the layer of that material will become thinner as the amount of material lessens away from the source.

Often, coarser-grained material can no longer be transported to an area because the transporting medium has insufficient energy to carry it to that location. In its place, the particles that settle from the transporting medium will be finer-grained, and there will be a lateral transition from coarser- to finer-grained material. The lateral variation in sediment within a stratum is known as sedimentary facies.

If sufficient sedimentary material is available, it will be deposited up to the limits of the sedimentary basin. Often, the sedimentary basin is within rocks that are very different from the sediments that are being deposited, in which the lateral limits of the sedimentary layer will be marked by an abrupt change in rock type.

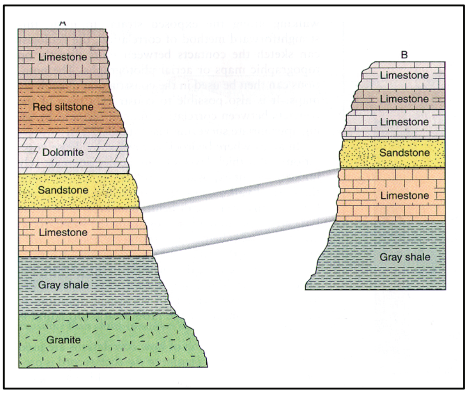


Figure 5. *Schematic representation of the principle of lateral continuity. Rock units in (A) can be correlated with those in (B).*

Faunal succession

The principle of faunal succession is based on the appearance of fossils in sedimentary rocks (Fig. 6). As organisms exist at the same time period throughout the world, their presence or (sometimes) absence may be used to provide a relative age of the formations in which they are found. Based on principles laid out by William Smith almost a hundred years before the publication of Charles Darwin's theory of evolution, the principles of succession were developed independently of evolutionary thought. The principle becomes quite complex, however, given the uncertainties of fossilisation, the localisation of fossil types due to lateral changes in habitat (facies change in sedimentary strata), and that not all fossils may be found globally at the same time.

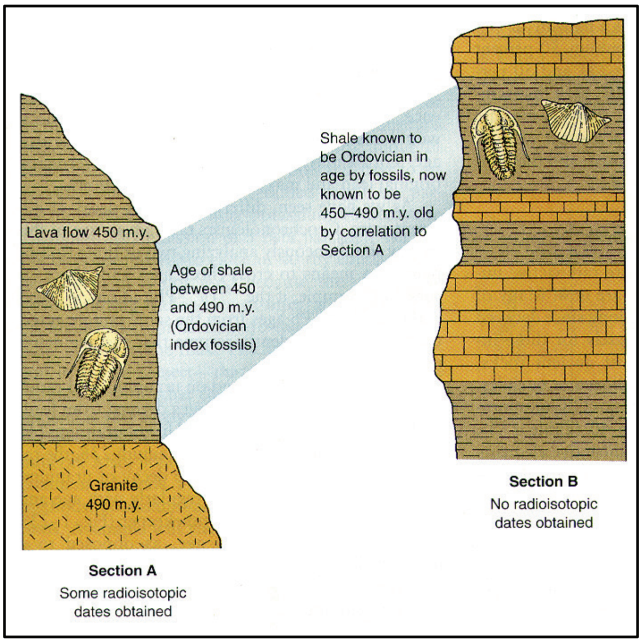


Figure 6. *Principle of faunal succession. Rock units containing the same index fossils are of the same age.*

Inclusions of igneous rocks

Melt inclusions are small parcels or "blobs" of molten rock that are trapped within crystals that grow in the magmas that form igneous rocks (Fig. 7). In many respects they are analogous to fluid inclusions. Melt inclusions are generally small – most are less than 100 micrometres across (a micrometre is one thousandth of a millimetre, or about 0.00004 inches). Nevertheless, they can provide an abundance of useful information. Using microscopic observations and a range of chemical microanalysis techniques geochemists and igneous petrologists can obtain a range of useful information from melt inclusions. Two of the most common uses of melt inclusions are to study the compositions of magmas present early in the history of specific magma systems. This is because inclusions can act like "fossils" – trapping and preserving these early melts before they are modified by later igneous processes. In addition, because they are trapped at high pressures many melt inclusions also provide important information about the contents of volatile elements (such as H_2O, CO_2, S and Cl) that drive explosive volcanic eruptions.

The first to document microscopic melt inclusions in crystals was Sorby in1858. The study of melt inclusions has been driven more recently by the development of sophisticated chemical analysis techniques. Scientists from the former Soviet Union lead the study of melt inclusions in the decades after World War II, and developed methods for heating melt inclusions under a microscope, so changes could be directly observed.

Although they are small, melt inclusions may contain a number of different constituents, including glass (which represents magma that has been quenched by rapid cooling), small crystals and a separate vapour-rich bubble. They occur in most of the crystals found in igneous rocks and are common in the minerals quartz, feldspar, olivine and pyroxene. The formation of melt inclusions appears to be a normal part of the crystallization of minerals within magmas, and they can be found in both volcanic and plutonic rocks.

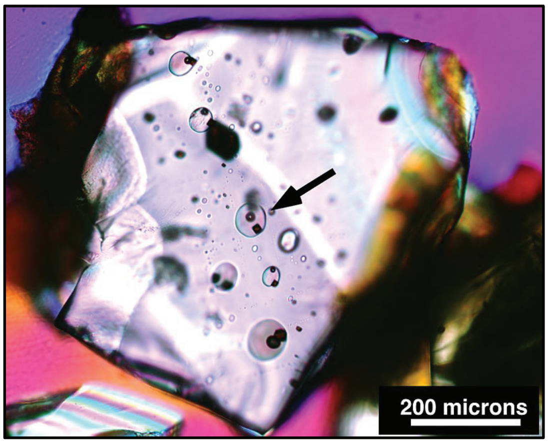


Figure 7. *Multiple melt inclusions in an olivine crystal. Individual inclusions are oval or round in shape and consist of clear glass, together with a small round vapour bubble and in some cases a small square spinel crystal. The black arrow points to one good example, but there are several others. The occurrence of multiple inclusions within a single crystal is relatively common.*

Included fragments

The law of included fragments is a method of relative dating in geology. Essentially, this law states that clasts in a rock are older than the rock itself. One example of this is a xenolith, which is a fragment of country rock that fell into passing magma as a result of stoping. Another example is a derived fossil, which is a fossil that has been eroded from an older bed and redeposited into a younger one.

This is a restatement of Charles Lyell's original principle of inclusions and components from his 1830 to 1833 multi-volume Principles of Geology, which states that, with sedimentary rocks, if inclusions (or clasts) are found in a formation, then the inclusions must be older than the formation that contains them. For example, in sedimentary rocks, it is common for gravel from an older formation to be ripped up and included in a newer layer. A similar situation with igneous rocks occurs when xenoliths are found. These foreign bodies are picked up as magma or lava flows, and are incorporated, later to cool in the matrix. As a result, xenoliths are older than the rock which contains them.

2. Principles of stratigraphy 2

Stratigraphy is the study of rock layers and reconstruction of the original sequence in which they were deposited. The stratigraphy of an area provides the basis for putting together the geologic history of an area.

What are the principles of relative geologic age determination?

(a) The principle of original horizontality - sedimentary strata are initially deposited as horizontal or nearly horizontal layers.
Note: If sedimentary strata dip at an angle other than horizontal, or are folded into various angles of tilt, then the layers of rock have been tilted or folded after the layers originally formed.

(b) The principle of lateral continuity - sedimentary strata extend sideways for some distance.
Note: If a sedimentary stratum occurs on one side of a stream valley and a seemingly identical stratum occurs at a corresponding level on the other side of the valley, then presumably they were once a single, laterally continuous layer that was later partly eroded away as the valley was eroded.

(c) The principle of superposition - In a sequence of sedimentary strata, the stratum that is underneath is older, the stratum that is on top is younger.
Note: This is probably the simplest and yet most powerful principle of relative age determination. However, to make sure it correctly applied, you need to be sure which way was up when the sediments were initially deposited, because in some geologic structures (faults or folds) it is possible for a layer of rock to be turned completely upside-down.

(d) The principle of inclusions - A piece of rock that is included in (completely surrounded by) sedimentary rock is older than the sedimentary rock in which it is included.
Note: If rounded pieces of granite are pebbles in a layer of conglomerate that lies on top of the granite, then the granite must have been exposed, weathered and eroded prior to the conglomerate being deposited.

(e) The principle of cross-cutting relationships - A rock body or geologic structure that cuts off other layers or structures that would otherwise tend to continue is younger than the layers or structures that it cuts off.
Note: If sedimentary beds are cut off by a fault, then the fault must be younger than the layers of sediment.

(f) Principle of faunal succession - Within a geologic era, period, or epoch there are certain fossil types that occur in strata of that age that are not found in strata of other ages.
Note: This principle is a powerful tool for determining the age of sedimentary rocks. Index fossils are ones that only occur within limited intervals of geologic time. Much geological research has been done to determine the extent of geologic time through which particular index fossils occurred.

By the end of the 19th century, geologists had used these principles to put together an outline of the geological history of the world, and had defined and named the eons, eras, periods, and epochs of the geologic time scale. They did not know how many thousands, millions, or billions of years ago the Cambrian period began, but they knew that it came after the Proterozoic Eon and before the Ordovician Period, and that the fossils unique to Cambrian rocks were younger than Proterozoic fossils and older than Ordovician ones.

In the 20th century, radiometric methods of absolute age determination were developed. These methods allow the ages of certain types of rocks and minerals to be quantified in terms of years. By the 1960s absolute dating methods had been used to determine the ages of many rocks from all the continents and ocean floors. Repeatedly, the absolute age determinations confirmed what geologists already knew, for example that the Cambrian period occurred before-is older than-the Ordovician period. The absolute dating methods proved that the relative dating methods had been correct, and now geologists can say not only state the sequence of geologic time, they can also estimate fairly accurately how many years ago each division in the sequence occurred.

How do unconformities mark missing time?

Another essential concept in stratigraphy is the unconformity. An unconformity is a surface upon which no new sediments were deposited for a long geologic interval. During this interval, erosion may have occurred before more deposits of sediments covered the surface. An unconformity marks a "gap in geologic time" because the rocks below and above it come from widely separated geologic times. There are no sedimentary strata to record what happened during the intervening interval. Instead, there is just an unconformity, a buried erosional or non-depositional surface.

Unconformities separate chapters in the geologic history of a given region. For instance, an orogenic episode (a long geologic episode of mountain building) may finally come to end and the eroded mountains may be buried beneath a new sequence of sediments. A major unconformity would mark the change from the building up of mountains to the wearing down of those same mountains and the subsequent blanketing of the area with sediments.

There are several specific types of unconformities. The three major, specific types of unconformities are included here.

The key to identifying each specific type of unconformity is recognizing what the unconformity is on top of. The possibilities for what is in the rocks immediately beneath the unconformity are (a) layers of sedimentary or volcanic rock (strata) that have been tilted or folded prior to development of the unconformity; (b) a stratum is parallel to the unconformity and parallel to the stratum above the unconformity; or (c) plutonic or metamorphic rocks, which originated much deep in the earth's crust rather than at its surface.

An ***angular unconformity* is** an unconformity beneath which the strata were tilted or folded before deposition of the younger layers of sediment above the unconformity (Fig. 8). After being tilted or folded, the older layers of sediment were eroded. Then younger layers of sediment were deposited on them. The angular unconformity is the contact between the younger layers of sediment and the older, tilted strata beneath.

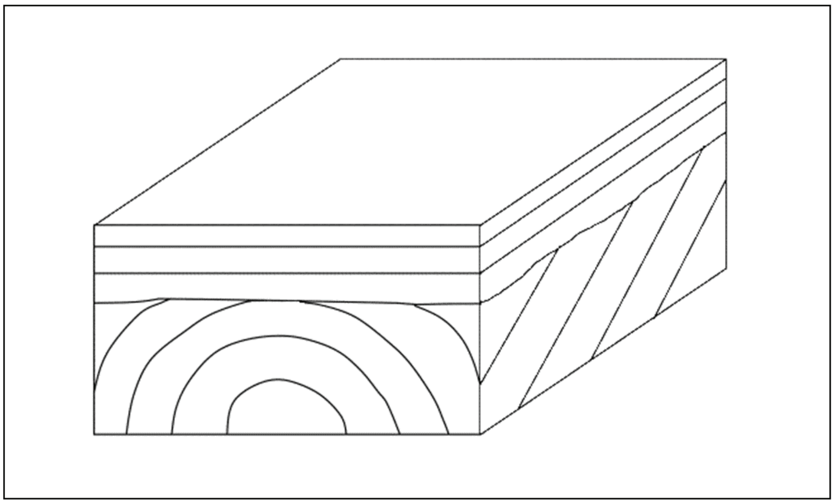


Figure 8. *An angular unconformity*

A ***nonconformity*** is an unconformity with sedimentary or volcanic strata on top and, beneath it, either plutonic rock such as granite or metamorphic rock such as schist. Because granitic and metamorphic rocks form deep in the earth's crust, a significant amount of time is required for uplift and erosion to expose them. Nonconformities mark major chapter breaks in the geologic history of an area.

In the example below (Fig. 9), the contact between the conglomerate and the granite beneath it appears likely to be a nonconformity. However, it is possible that the granite may have intruded as a magma within the crust, beneath conglomerate, after the conglomerate formed. If so, the granite is younger and the boundary between the granite and the conglomerate is an intrusive contact rather than a nonconformity. To determine the nature of the contact - whether it is an intrusive contact or a nonconformity - further evidence from field investigations would be needed. Evidence such as angular pieces of conglomerate surrounded by the granitic intrusion, and contact metamorphism of the conglomerate adjacent to the granite, would indicate that the granite is younger and intruded the older conglomerate. Evidence such as rounded pebbles of the granite within the conglomerate would indicate that the granite is older and underwent erosion prior to the conglomerate forming, and the contact is a nonconformity.

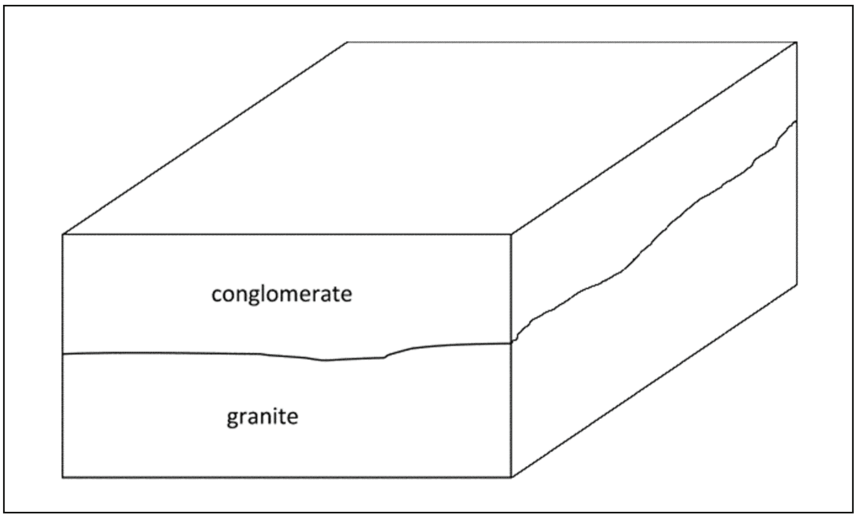


Figure 9. *A non-conformity*

A ***disconformity*** is an unconformity with a sedimentary stratum beneath it that is not folded or tilted relative to the unconformity. Because there is a layer of sedimentary rock below a disconformity that is parallel to the layer above it, a disconformity may be difficult to recognize. The existence of a disconformity is indicated by the geologic ages of the sedimentary strata. If there is a significant gap in geologic time between the two layers - for example, if the layer beneath is Cambrian in age and the layer above is Devonian in age - then it can be inferred that the contact between the layers is a disconformity. Confirming evidence of a disconformity may include signs of erosion into the lower layer, and soil development on top of it, prior to deposition of the sediment of the upper layer.

In the example below (Fig. 10), it appears that the contact between layers ***b*** and ***c*** may be a buried erosional surface. If the geologic ages of the strata show a significant gap in geologic time between stratum ***b*** and stratum ***c***, then the contact between them is a disconformity.

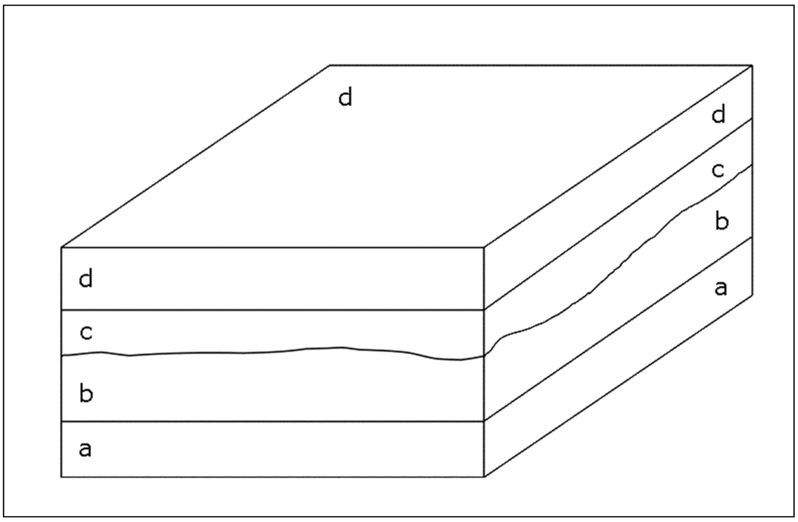


Figure 10. *A disconformity*
(Source: https://commons.wvc.edu/rdawes/Basics/stratigraphy.html)

3. Applications of stratigraphic principles

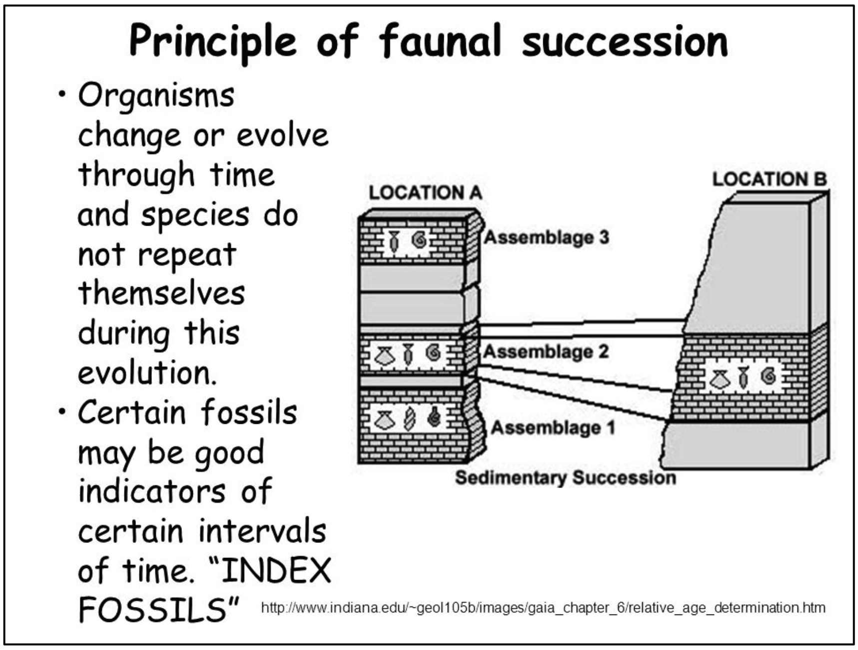
The principle of faunal succession, also known as the **law of faunal succession**, is based on the observation that sedimentary rock strata contain fossilized flora and fauna, and that these fossils succeed each other vertically in a specific, reliable order that can be identified over wide horizontal distances. A fossilized Neanderthal bone will never be found in the same stratum as a fossilized Megalosaurus, for example, because Neanderthals and Megalosaurs lived during different geological periods, separated by many millions of years. This allows for strata to be identified and dated by the fossils found within.

This principle, which received its name from the English geologist William Smith, is of great importance in determining the relative age of rocks and strata. The fossil content of rocks together with the law of superposition helps to determine the time sequence in which sedimentary rocks were laid down.

Evolution explains the observed faunal and floral succession preserved in rocks. Faunal succession was documented by Smith in England during the first decade of the 19th century, and concurrently in France by Cuvier (with the assistance of the mineralogist Alexandre Brongniart). Archaic biological features and organisms are succeeded in the fossil record by more modern versions. For instance, palaeontologists investigating the evolution of birds predicted that feathers would first be seen in primitive forms on flightless predecessor organisms such as feathered dinosaurs. This is precisely what has been discovered in the fossil record: simple feathers, incapable of supporting flight, are succeeded by increasingly large and complex feathers.

In practice, the most useful *diagnostic species* are those with the fastest rate of species turnover and the widest distribution; their study is termed biostratigraphy, the science of dating rocks by using the fossils contained within them. In Cainozoic strata, fossilised tests of foraminifera are often used to determine faunal succession on a refined scale, each biostratigraphic unit (biozone) being a geological stratum that is defined based on its characteristic fossil taxa.

Simply, the earlier fossil life forms are simpler than more recent forms, and more recent forms are most similar to existing forms (principle of faunal succession).



Principle of faunal succession

- Organisms change or evolve through time and species do not repeat themselves during this evolution.
- Certain fossils may be good indicators of certain intervals of time. "INDEX FOSSILS"

http://www.indiana.edu/~geol105b/images/gaia_chapter_6/relative_age_determination.htm

Figure 11. *The principle of faunal succession.*
(https://en.wikipedia.org/wiki/Principle_of_faunal_succession)

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (notes, charts, and pictures) and ask questions on the principles of relative dating and their limitations.	Students will use the information provided to answer questions on the principles of relative dating and their limitations.

STEAM Approach

Learning Objective: By the end of the topic, students will be able to;

- Analyse and understand the principles of relative dating and their limitations – STEAM

Teaching Strategies	Learning Strategies
Teachers will provide the information for students to read, observe and answer questions within a given period of time.	Students read the notes and use the materials available to understand the principles of relative dating and their limitations.

Recommended Resources:

- Davidson, J.P., Reed, W.E., and Davis, P.M., 1997. Exploring Earth. An Introduction to Physical Geology, Prentice-Hall Inc., 264p.
- Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p
- https://en.wikipedia.org/wiki/Absolute_dating
- https://en.wikipedia.org/wiki/Principle_of_faunal_succession
- Internet

Unit 3: Earthquakes and Volcanoes

Content Standard	**12.2.3** Students will be able to understand and explore the processes of earthquakes and volcanoes.
Benchmark	**12.2.3.1** Analyse the process of earthquakes.

Topic 1 : Earthquakes

Learning Objectives:

By the end of this topic, the students will be able to:

- Relate elastic rebound theory to the generation of earthquakes.
- Describe the properties of body waves and surface waves.
- Describe the generation and propagation of earthquake body waves (P- and S-waves) and surface waves.
- Identify and give evidences to support the conclusion that the Earth is layered (P- and S-waves)
- Explain how a seismograph works (e.g. model or diagram).
- Distinguish between earthquake magnitude and earthquake intensity.
- Identify and locate the epicentre of an earthquake, given appropriate earthquake data.
- Explain the methods of earthquake prediction (e.g., dilatancy data, seismic gap, animal behaviour)
- Describe earthquake effects, earthquake hazards, and methods of preparedness for such natural disasters.
- Explain the seismic risk in relation to earthquake.

Essential questions

1. How can we relate rebound theory to the generation of earthquakes?
2. What are the properties of body waves and surface waves?
3. How can we describe the travel paths of body waves through the earth?
4. What evidence does support that Earth is layered?
5. How does a seismograph works?
6. What is the difference between earthquake magnitude and earthquake intensity?
7. How can we locate the epicentre of an earthquake?
8. What are some methods of earthquake prediction?
9. What are some hazards and effects of earthquake?
10. What is seismic risk in relation to earthquake?

Vocabulary: Elastic rebound theory, body waves, surface waves, seismograph, Richter scale, Mercalli scale, hazards, earthquake

Concepts	Essential Skills	Essential Values and Attitudes
• Earthquake rebound theory • Body waves and surface waves • Travel paths of body waves through the Earth • Earth's layering • Seismograph • Earthquake magnitude and intensity • Locating epicentre • Predicting earthquakes • Hazards and effects of earthquakes • Seismic risk	• Making generalisations • Reasoning • Analysing • comparing and contrasting • Modelling	Open-minded, desire to learn, being responsible, critical

Content Background

1. Earthquake rebound theory

Elastic Rebound Theory – is an explanation for how energy is released/ spread during Earthquakes. As rocks on opposite sides of a fault are subjected to force and shift, the accumulate energy and slowly deform until their internal strength is exceeded.

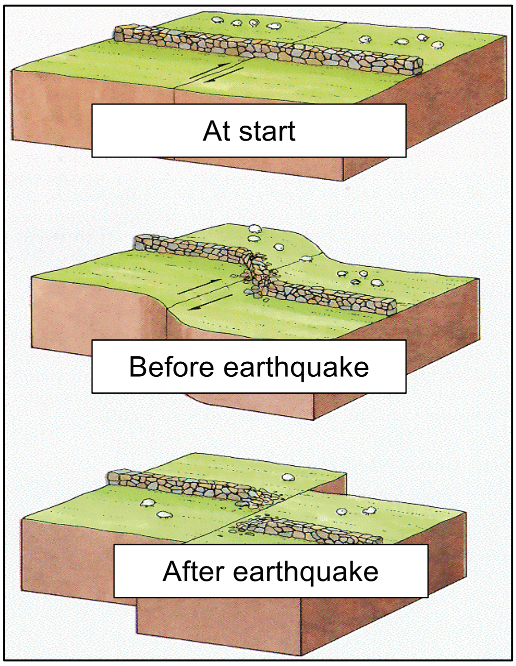


***Figure 1**. Elastic rebound theory*
(Source: /https://mrleehamber119.wordpress.com/earthquake-elastic-rebound-theory/)

Then they separate with a rupture along the fault line (which would be between 5 and 6 on the diagram); the sudden movement releases accumulated energy, and the rocks snap back almost to their original shape. The previously solid mass is divided between the two slowly moving plates, the energy released to the surroundings in all directions (seismic wave).

Theory

After the great 1906 San Francisco earthquake, geophysicist Harry Fielding Reid examined the displacement of the ground surface along the San Andreas Fault in the 50 years before the earthquake. He found evidence for 3.2 m of bending during that period. He concluded that the quake must have been the result of the elastic rebound of the strain energy stored in the rocks on either side of the fault. Later measurements using the global positioning system largely support Reid's theory as the basis of seismic movement.

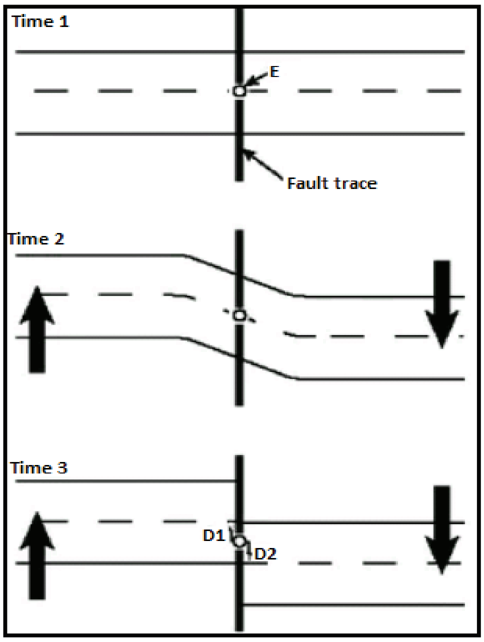


Figure 2. *Diagram showing the how elastic rebound theory occurs* (Source: https://en.wikipedia.org/wiki/Elastic rebound_theory)

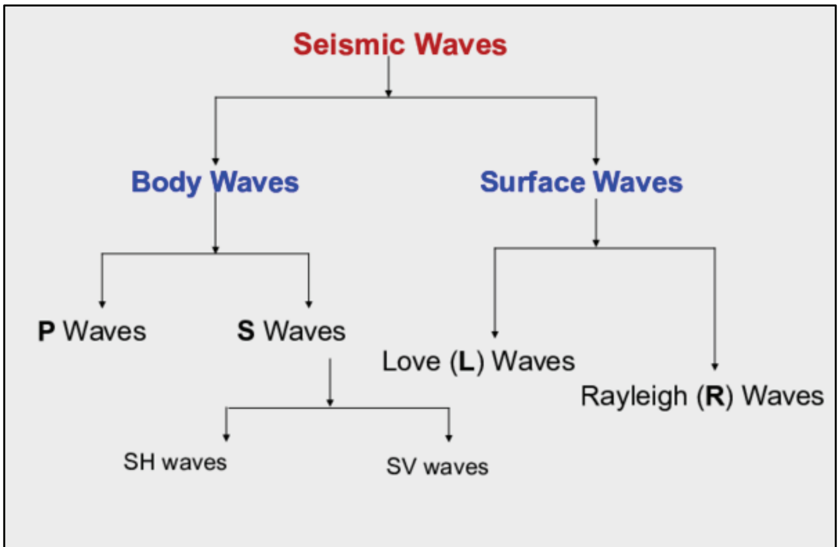
Explanation

The two sides of an active but locked fault are slowly moving in different directions, where elastic strain energy builds up in any rock mass that adjoins them. Thus, if a road is built straight across the fault as in Time 1 in the figure, it is perpendicular to the fault trace at point E, where the fault is locked. The overall fault movement (large arrows) causes the rocks across the locked fault to accrue elastic deformation, as in Time 2. This deformation may build at the rate of a few centimetres per year. When the accumulated strain is great enough to overcome the strength of the rocks, the result is a sudden break, or a springing back to the original shape as much as possible, a jolt which is felt on the surface as an earthquake. This sudden movement results in the shift of the road surface, as shown in Time 3. The stored energy is released partly as heat, partly in alteration of the rock, and partly as a seismic wave.

In earthquakes these ruptures generally happen along fault planes, or lines of weaknesses in the Earth's crust.

2. Body waves and surface waves

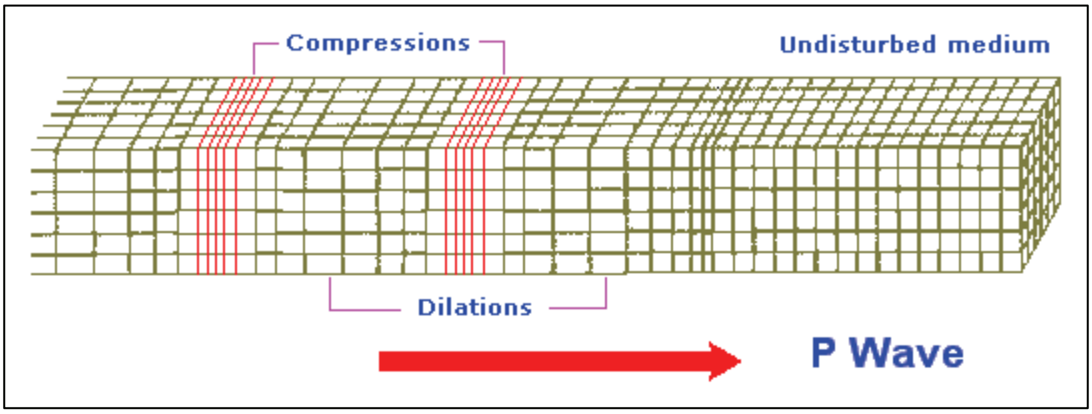
Seismic surface waves travel along the Earth’s surface. They can be classified as a form of mechanical surface waves. They are called surface waves, as they diminish as they get further from the surface. They travel more slowly than seismic body waves (P and S). In large earthquakes, surface waves can have an amplitude of several centimetres.



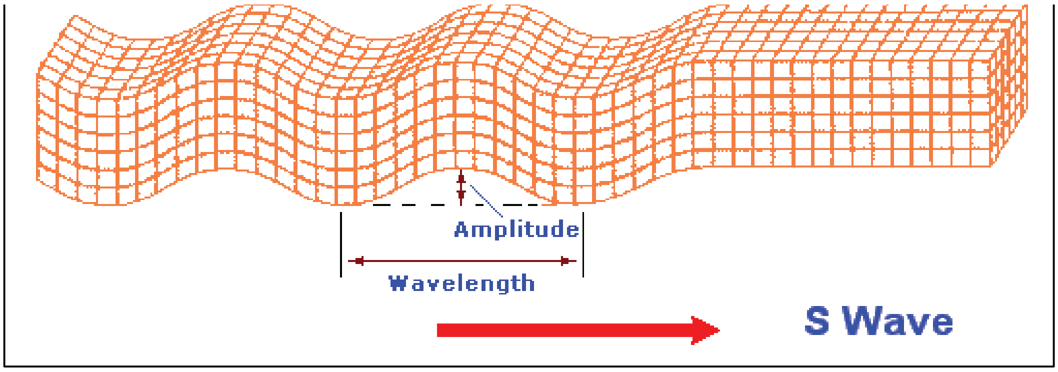
- Body waves travel through the interior of the Earth.
- Surface waves: Their motion is restricted to near the ground surface.

Three types of earthquake waves: P (Primary) waves, S (Secondary) waves and L/R (Love & Rayleigh) waves:

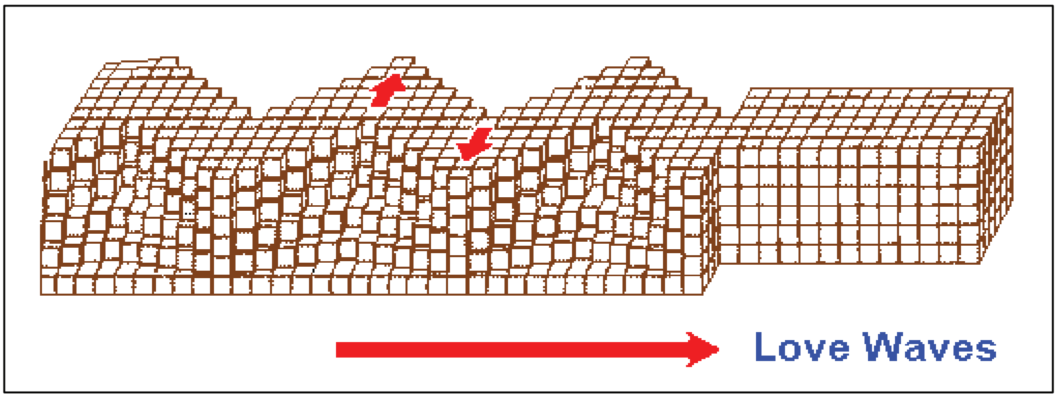
A. P (stands for prima, Latin for first)- Its motion is the same as that of a sound wave in that, as it spreads out, it alternately pushes (compresses) and pulls (dilates) the rock. These P waves are able to travel through both solid rock, such as granite mountains, and liquid material, such as volcanic magma or the water of the oceans:



B. S (stands for secunda, Latin for second) - The slower wave through the body of rock is called the secondary or S wave. As an S wave propagates, it shears the rock sideways at right angles to the direction of travel. If a liquid is sheared sideways or twisted, it will not spring back, hence S waves cannot propagate in the liquid parts of the earth, such as oceans and lakes:



C. Love & Rayleigh waves- The third general type of earthquake wave is called a surface wave, reason being is that its motion is restricted to near the ground surface. Such waves correspond to ripples of water that travel across a lake. Surface waves in earthquakes can be divided into two types. The first is called a Love wave. Its motion is essentially that of S waves that have no vertical displacement; it moves the ground from side to side in a horizontal plane but at right angles to the direction of propagation. The horizontal shaking of Love waves is particularly damaging to the foundations of structures:



The second type of surface wave is known as a Rayleigh wave. Like rolling ocean waves, Rayleigh waves move both vertically and horizontally in a vertical plane pointed in the direction in which the waves are travelling:

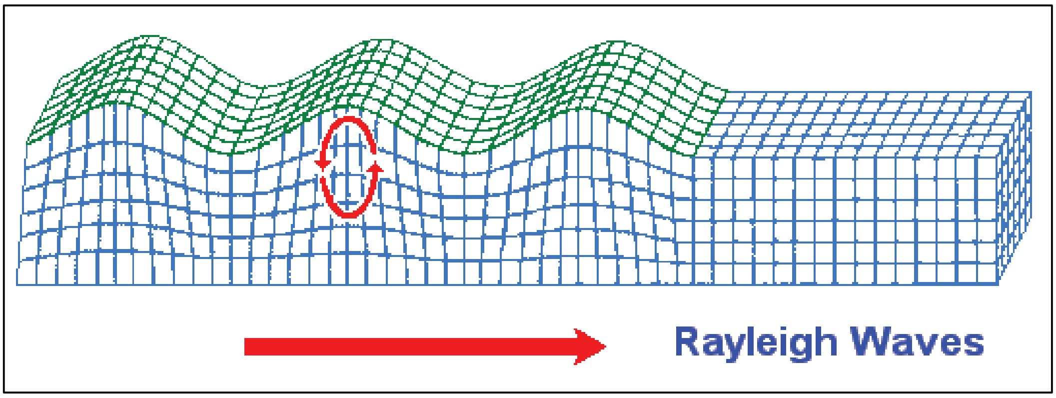


Figure 3. *Different types of earthquake waves*
(Images and information source: http://www.allshookup.org/quakes/wavetype.htm)

3. Travel paths of body waves through the Earth

The path that a wave takes between the focus and the observation point is often drawn as a ray diagram. An example of this is shown in the figure above. When reflections are taken into account there are an infinite number of paths that a wave can take. Each path is denoted by a set of letters that describe the trajectory and phase through the Earth. In general an upper case denotes a transmitted wave and a lower case denotes a reflected wave. The exceptions to this seem to be “g” and “n”.

The paths of the seismic waves from the epicentre of an earthquake (i.e. the point on the earth’s surface directly above the origin of the earthquake) are shown in the figure below.

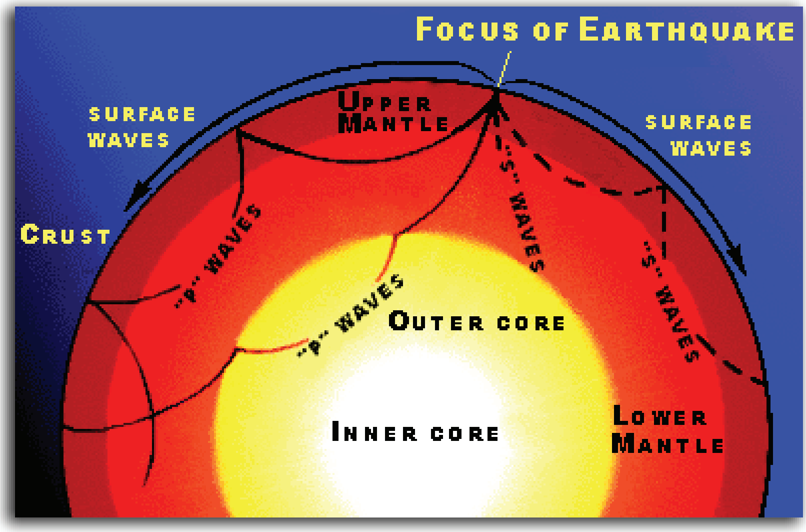


Figure 4. *Typical paths of an Earthquake's seismic waves through the interior of the Earth (Source: USGS).*

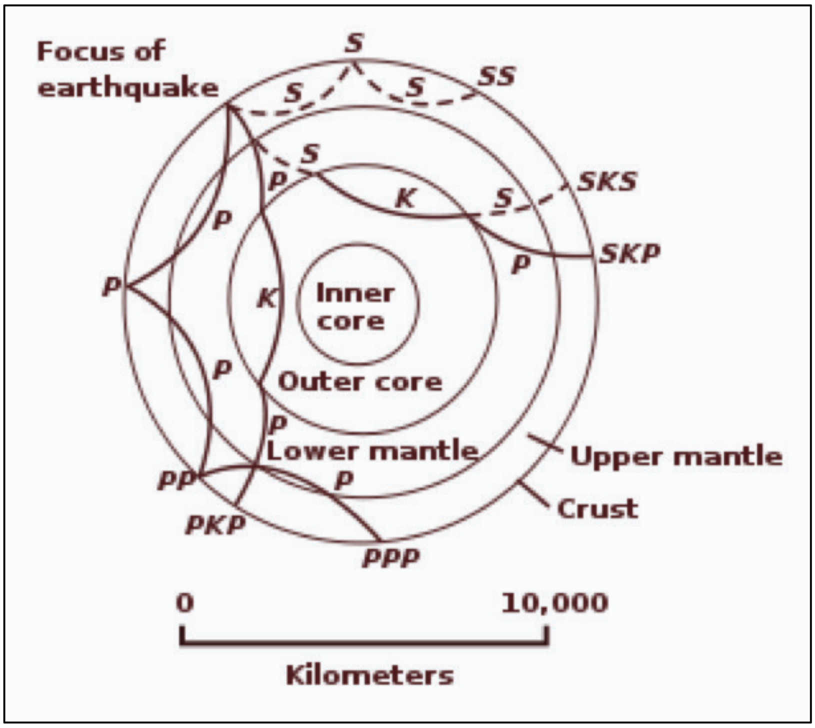


Figure 5. *Earthquake waves paths* (Source: https://www.jing.fm/iclip/u2q8e6r5u2a9e6r5_what-type-of-seismic-waves-travel-through-earth/)

When an earthquake occurs, seismographs near the epicenter are able to record both P and S waves, but those at a greater distance no longer detect the high frequencies of the first S wave. Since shear waves cannot pass through liquids, this phenomenon was original evidence for the now well-established observation that the earth has liquid outer core. This kind of observation has also been used to argue, by seismic testing, that the Moon has a solid core, although recent geodetic studies suggest that the core is still molten.

Notation

The path that a wave takes between the focus and the observation point is often drawn as a ray diagram. An example of this is shown in the figure above. When reflections are taken into account there are an infinite number of paths that a wave can take. Each path is denoted by a set of letters that describe the trajectory and phase through the Earth. In general an upper case denotes a transmitted wave and a lower case denotes a reflected wave. The exceptions to this seem to be “g” and “n”.

Symbol	**Meaning**
c	The wave reflects off the outer core
d	A wave that has been reflected off a discontinuity at depth d
g	A wave that only travels through the crust
i	A wave that reflects off the inner core
I	A P-wave in the inner core
h	A reflection of a discontinuity in the inner core
J	An S-wave in the inner core
K	A P-wave in the outer core
L	A Love wave sometimes called LT wave (Both Caps, while as Lt is different)
n	Boundary between the crust and the mantle
P	A P-wave in the mantle
p (small letter)	A P-wave ascending to the surface from the focus
R	A Rayleigh wave
S	An S-wave in the mantle
s	An S-wave ascending to the surface from the focus
w	The wave reflects off the bottom of the ocean
No letter is used when the wave reflects off the surfaces and into the atmosphere	

For example:

- ScP – is a wave that begins traveling towards the centre of the Earth as an S-wave. Upon reaching the outer core the wave reflects as a P-wave.
- sPKIKP – is a wave path that begins traveling towards the surface as an S-wave. At the surface it reflects as a P-wave. The P-wave then travels through the outer core, the inner core, the outer core, and the mantle.

4. Evidence of Earth's layering

There are many ways scientists can gather evidence to learn about Earth's interior including direct evidence from rock samples and indirect evidence from seismic waves.

Below are some resources to help you understand how scientists infer the different layers of Earth's interior:

(a) Seismic waves and earthquakes
(b) Volcanoes
(c) Principles of density
(d) Earth is magnetic

Density Layering

As our planet became a molten mass, layers formed (Figs. 6 & 7). The densest material, containing iron and nickel, settled to the core in the centre of the Earth. Less dense matter, containing iron rich silicates - compounds of silicon and oxygen - formed the vast interior mantle. The least dense materials, such as common granite and basalt rock, rose to the surface, cooled, and formed the earth's solid, stony crust.

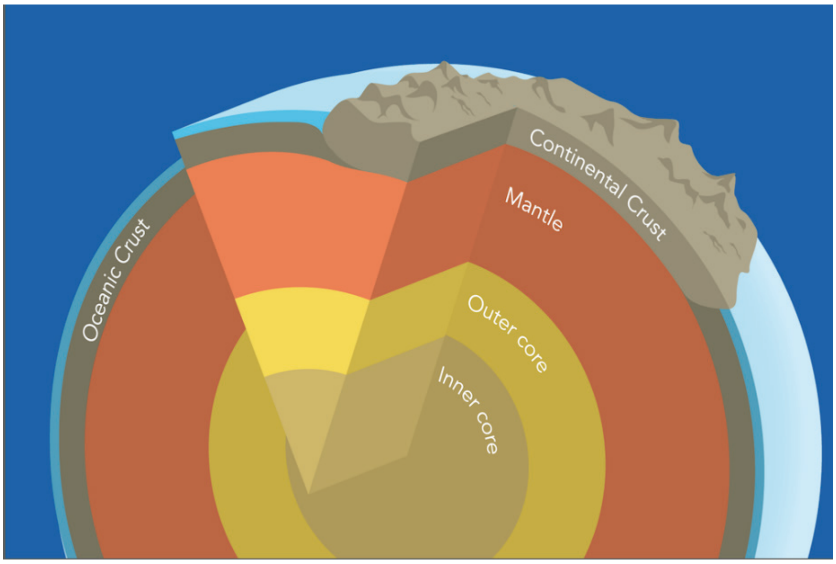


Figure 6. *This graphic representation of the earth's layers shows the inner core, the outer core, the mantle, and the oceanic and continental crusts (not to scale)* (Image by Byron Inouye)*.*

Volcanic eruptions through the stony outer crust continued to release heat and pressure from the molten centre of the earth. Each eruption brought gases, water vapour, ash, and molten lava to the surface from the interior. When the earth's surface cooled enough, the water vapour condensed into liquid, forming oceans. Volcanic activity continues to reshape the surface features of our planet.

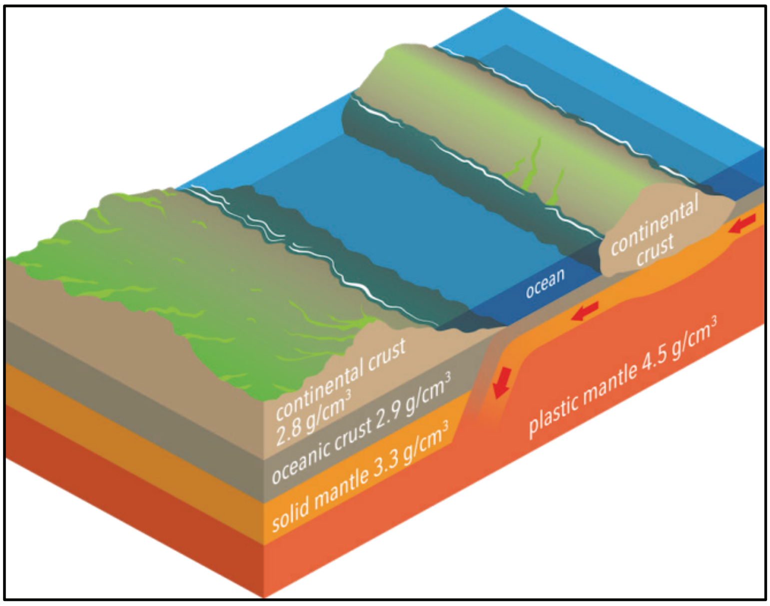


Figure 7. *This idealised cross-section of the earth's outer layers shows the densities of the earth's crust and upper mantle* (Image by Byron Inouye).

Different types of evidence support the hypothesis that the earth's interior is composed of layers of materials of different densities. Density is the amount of mass in a given volume of material.

The densities of some materials - granite and basalt, for example, can be determined from rock samples in the laboratory by measuring their mass and their volume. Fig. 8 shows the basic procedures for determining mass and volume of a rock sample. For precise measurements of the density of different kinds of rock material, pure samples must be used.

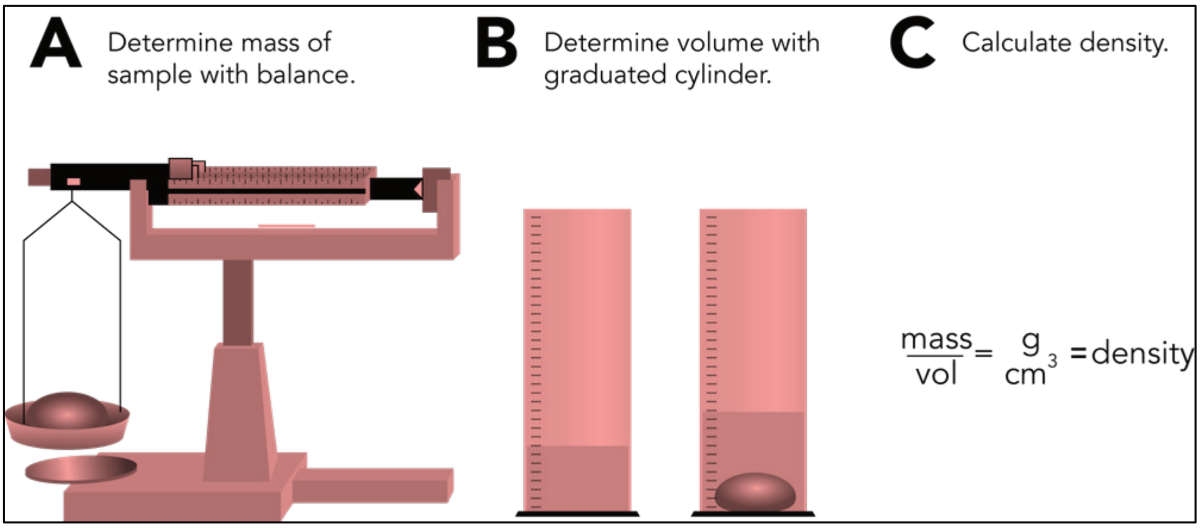


Figure 8. *Procedures for determining density of rock samples* (Image by Byron Inouye).

From direct laboratory measurements of surface rocks, scientists have determined that the average density of the earth's surface is about 2.8 g/cm^3. Indirect evidence indicates that the density of earth as a whole is about 5.5 g/cm^3. This suggests that the interior of the earth must be denser than the crust.

There is evidence that the materials within the earth form distinct layers, each with a different density. Most of this evidence comes from observations of seismic waves, the vibrations generated by earthquakes or explosions. As seismic waves travel through the earth, changes in wave patterns indicate where the waves are reflected or refracted in the earth's interior. Careful measurement of changes in the velocity of these waves as they travel through the earth has provided information about the number of layers, their thickness, and their composition. These data also indicate the probable physical state of each layer, whether it is solid rock, a molten liquid, or a tarry plastic substance.

Scientists are still unable to obtain and test samples of materials from deep within the earth. However, they can compare data from earth vibration observations with data from simulated laboratory tests on materials of known chemical composition. They can also construct and test computer models of the physical features of the earth. From these data, scientists have inferred that our earth is made of layers of material of different densities.

5. Seismograph

A seismograph, or seismometer, is an instrument used to detect and record earthquakes. Generally, it consists of a mass attached to a fixed base. During an earthquake, the base moves and the mass does not.

How are earthquakes measured?

A device called a seismograph is used to record earthquakes. The base of the seismograph is inserted into the Earth and shakes accordingly with an earthquake while a pen that is attached to a motionless weight does not. The difference in movement is recorded on the paper directly below the pen, and the recording is thus known as a seismograph.

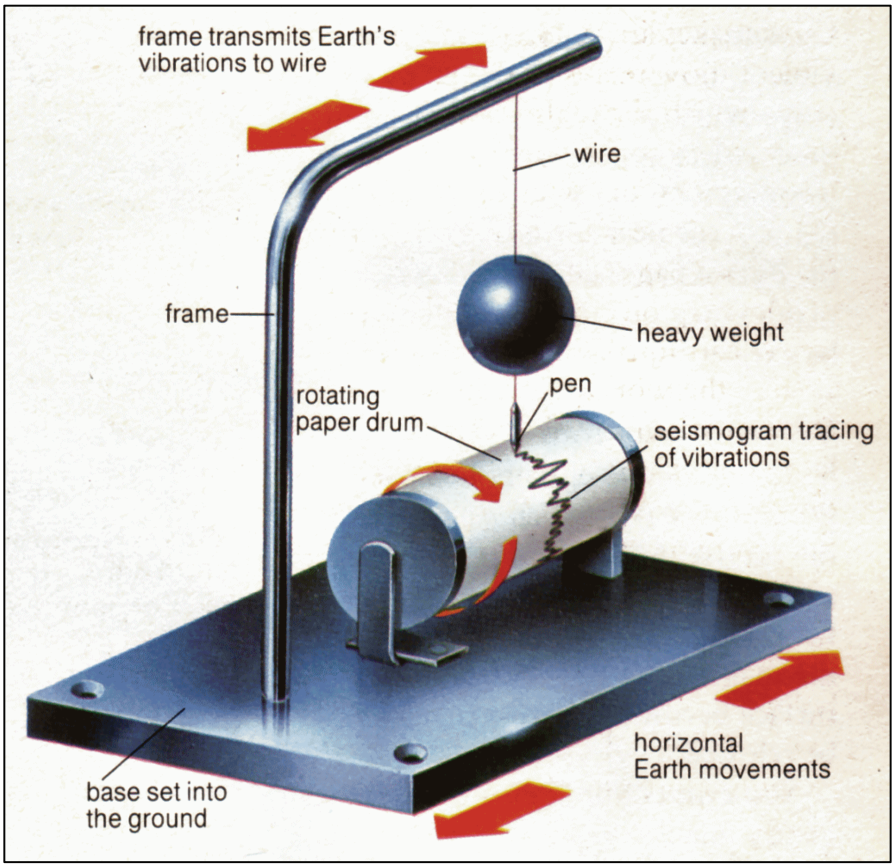


Figure 9. *A typical seismograph*
(Source: https://benignlaughter.com/2014/06/04/how-are-earthquakes-measured/)

Seismogram

The wiggly lines across the seismogram are all seismic waves that the seismograph has recorded. Most of these lines were so small that nobody felt them. These tiny microseisms can be caused by heavy traffic near the seismograph, waves hitting a beach, the winds, and any number of ordinary things that cause some shaking of the seismograph. There also may be some little dots or marks evenly spaced along the paper. These are marks for every minute that the drum of the seismograph has been turning. How far apart these minute marks are will depend on what type of seismograph you have.

The P wave will be the first wiggle that is bigger than the rest of the little ones (microseisms). Because P waves are the fastest seismic waves, they will usually be the first to be recorded. The next set would be S-waves, followed by surface waves (see figure below).

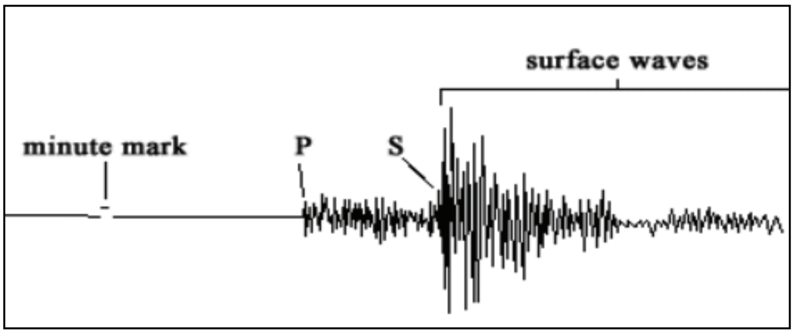


Figure 10. *A typical seismogram*

6. Earthquake magnitude and intensity

Magnitude and Intensity measure different characteristics of earthquakes. Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs. Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment.

Magnitude / intensity comparison

The following table gives intensities that are typically observed at locations near the epicenter of earthquakes of different magnitudes.

Magnitude	**Typical Maximum Modified Mercalli Intensity**
1.0 – 3.0	I
3.0 – 3.9	II – III
4.0 – 4.9	IV – V
5.0 – 5.9	VI – VII
6.0 – 6.9	VII – IX
7.0 and higher	VIII or higher

Abbreviated Modified Mercalli intensity scale

I. Not felt except by a very few under especially favourable conditions.

II. Felt only by a few persons at rest, especially on upper floors of buildings.

III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

7. Locating epicentre

The distance of the epicenter of an earthquake from a recording station (R) can be found from the time delay (ΔT) between the arrival of the first P and the first S waves, as R increases, ΔT becomes longer. From observation and analysis of a large number of earthquake records, detailed travel-time tables have been constructed enabling R to be accurately found from measurements of ΔT.

For example, if the time delays from recording stations A, B and C are:

$\Delta T_A = 2\text{min}$, $\Delta T_B = 3\text{min}$, $\Delta T_C = 5\text{min}$

And the corresponding distances of each station from the earthquake are:

$R_A = 1200$ km, $R_B = 1800$ km, $R_C = 3300$ km

If a circle of appropriate radius is drawn around each station as shown below, the earthquake occurred at the point of intersection (X) of all three circles. It is clear that records from at least three stations are needed to locate an earthquake epicenter accurately. Note that we use delay times between P and S waves, rather than the individual propagation times, as the exact time at which the earthquake occurred is not usually known.

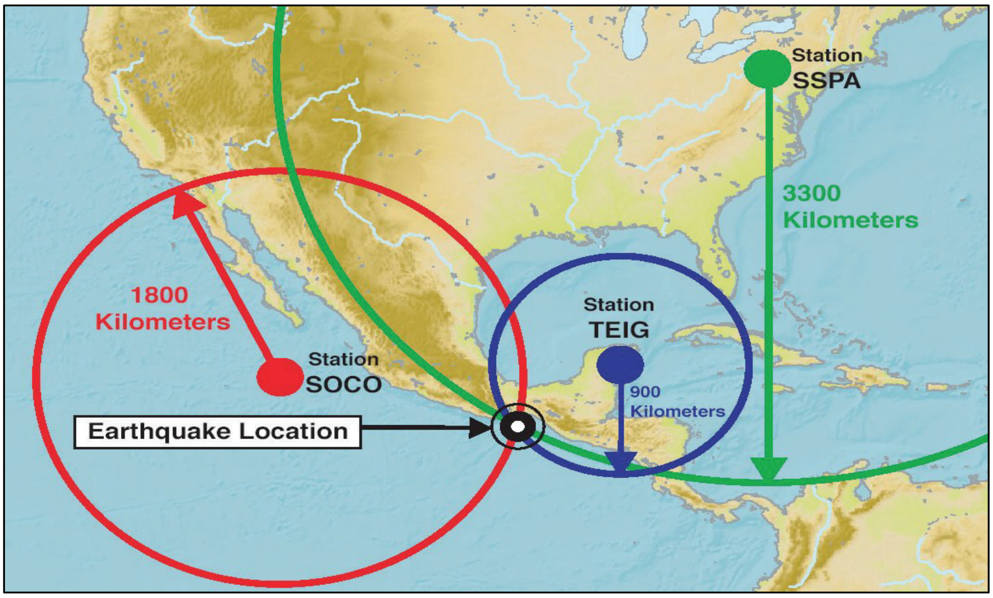


***Figure 11.** Locating the epicentre on an earthquake* (Source: www.rcsdk12.org)

8. Limitations in prediction of earthquakes

There were a lot of scientists both in the past and at present whom have attempted to predict the occurrence of an earthquake before it happened. They have used a variety of methods or techniques in doing so, however, most were not able to achieve the intended purpose. Some seismologists in a European country were even jailed for not providing the necessary information for public preparedness prior to a devastating earthquake. Few were able to predict after studying changes on the Earth's surface in terms of stress and strain on the rock beds which leads to a slow but continuous rise or fall of parts of the Earth's surface. However, they were not able to predict the actual time that the earthquake will actually occur. Scientists are still looking for a better method of determining earthquake and the actual time it will occur.

Some of the possible methods of predicting earthquake occurrence that scientists have tried studying so far but are not yet scientifically proven to be reliable areas are listed below.

- Studying animal behaviour
- Radon gas emissions
- Earthquake lights
- Electric signals
- Syzygy
- Ambient noise

9. Hazards and effects of earthquakes

The primary effects of earthquakes are ground shaking, ground rupture, landslides, tsunamis, and liquefaction. Fires are probably the single most important secondary effect of earthquakes.

Ground shaking

Ground shaking is the most familiar effect of earthquakes. It is a result of the passage of seismic waves through the ground, and ranges from quite gentle in small earthquakes to incredibly violent in large earthquakes. In the 27 March 1964 Alaskan earthquake, for example, strong ground shaking lasted for as much as 7 minutes! Buildings can be damaged or destroyed, people and animals have trouble standing up or moving around, and objects can be tossed around due to strong ground shaking in earthquakes.

***Figure 12**. Structural damage due to an earthquake* (Image by H.G. Wilshire, U.S. Geological Survey).

Ground Rupture

Ground rupture is another important effect of earthquakes which occurs when the earthquake movement along a fault actually breaks the Earth's surface. While active ground rupture is comparatively rare, there have been cases of it in California -- for example, during the 1906 earthquake, fences near Pt. Reyes were offset by as much as 7 meters. And in the Owens Valley earthquake in 1872, a fault scarp as much as 8 meters high broke the ground near Lone Pine. Rupture causes problems for humans by, well, rupturing things; pipelines, tunnels, aqueducts, railway lines, roads, and airport runways which cross an area of active rupture can easily be destroyed or severely damaged.

Landslides

Landslides are caused by earthquakes both by direct rupture and by sustained shaking of unstable slopes. They can easily destroy buildings in their path, or block roads and railroad lines, or take hilltop homes with them as they tumble. They even can dam rivers on occasion, like in the 17 August 1959 Hebgen Lake earthquake (magnitude 7.1) in Montana.

Figure 13. *Debris of road damage due to an earthquake (Image by C.E. Meyer, U.S. Geological Survey)*

Tsunamis

Tsunamis, which are popularly and incorrectly known as "tidal waves", are a grave hazard to many parts of the world, particularly around the Pacific Ocean basin. Tsunamis are a series of water waves caused when the seafloor moves vertically in an earthquake (which is why they are uncommon in California earthquakes (most California earthquakes are strike-slip, with little or no vertical motion and which can travel vast distances in a short period of time). Tsunami speeds in the deep ocean have been measured at more than 700 km/h, comparable to some jet planes, and when tsunamis reach shallow water near the coast, they can reach heights of more than 27 metres. Remember that tsunamis are a series of waves, and may start with a gentle withdrawal of water, followed by a very abrupt arriving wave, followed by another withdrawal, etc. The safest thing to do if you hear a tsunami is coming is to move to higher ground away from the beach as quickly as possible.

Liquefaction, subsidence and related effects

Liquefaction and subsidence of the ground are important effects which often are the cause of much destruction in earthquakes, particularly in unconsolidated ground. Liquefaction is when sediment grains are literally made to float in groundwater, which causes the soil to lose all its solidity. Subsidence can then follow as the soil re-compacts. Sand blows, or sand volcanoes, form when pressurized jets of groundwater break through the surface. They can spray mud and sand over an area a few metres across. All of these effects pose a grave danger to buildings, roads, train lines, airport runways, gas lines, etc. Buildings have actually tipped over and sunk partway into liquefied soils, as in the 1964 Niigata earthquake in Japan. Underground gas tanks and septic tanks have been known to float to the surface through liquefied soils. All told, liquefaction and associated effects resulted in more than US$20 billion damage in the 1995 Kobe earthquake, and similar levels of damage are possible in US port facilities during a large earthquake.

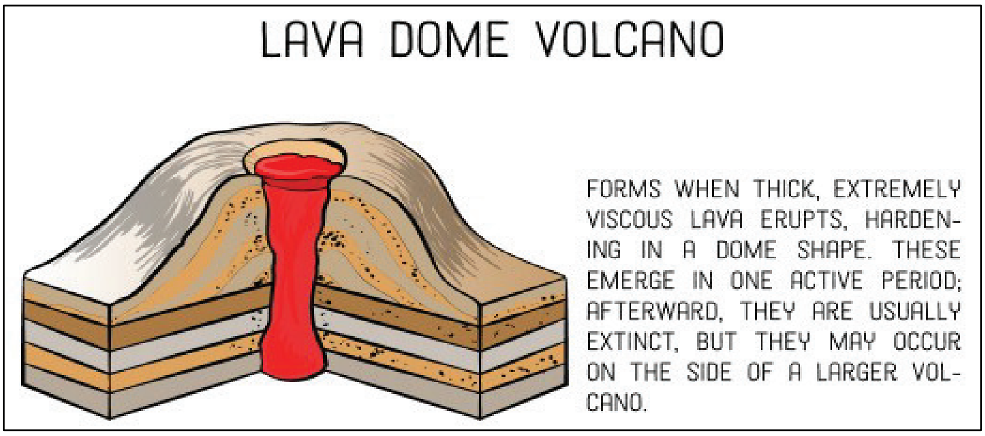
10. Seismic risk

Earthquake engineering

Modern cities that are built in high-risk zones, such as Tokyo and San Francisco, have a strict building code that requires that all structures must be designed to withstand earthquake shaking. Similarly, in Papua New Guinea there is a building code that requires certain standards of engineering, depending on the degree of seismic risk.

This seismic zoning section of the building code was prepared by Jury et al. (1982) for the Papua New Guinea National Standards Council with some consultation with sections of the PNG community, including the Port Moresby Geophysical Observatory

The zones are shown in Figure 14 superimposed on an earthquake map. Zone 1 is the most active seismic zone, in which the greatest building precautions need to be taken. Zone 4, which includes Port Moresby, is the least active zone. An International aseismic “Zero Zone”, in which no precautions need be to taken, would be equivalent to a non-existent Papua New Guinea Zone 5.



FORMS WHEN THICK, EXTREMELY VISCOUS LAVA ERUPTS, HARDENING IN A DOME SHAPE. THESE EMERGE IN ONE ACTIVE PERIOD; AFTERWARD, THEY ARE USUALLY EXTINCT, BUT THEY MAY OCCUR ON THE SIDE OF A LARGER VOLCANO.

Figure 8. *Diagram of lava dome volcano* (Source: https://owlcation.com/stem/4-Different-Types-of-Volcanoes-Cinder-Cones-Lava-Domes-Shield-and-Composite-Volcanoes)

5. Volcanic Hazards

(a) Primary effects of volcanism

Lava flows - lava flows are common in Hawaiian and Strombolian type of eruptions, the least

Zone 1 is the northern Solomon Sea triangle, including eastern New Britain, southern New Ireland and western Bougainville. The dangers are partly mitigated as most of the earthquakes of this zone occur in the northern Solomon Sea, some distance from land. Hence Rabaul, for example, is continually shaken at Intensity 4 (moderately shaken but no damage) or Intensity 5 (strong shake, threshold of breakages) by large earthquakes some 100-200 km distant.

Zone 2 includes the northern coast of the mainland of PNG, the length of which has experienced damaging earthquakes over the years, and western New Britain. Zone 3 includes the seismic zone of the Papuan Fold Belt, extending from Tabubil to Kerema, the northern section of Southeast Papua, Manus Island and northwestern New Ireland. Zone 4 includes Port Moresby and Daru.

Despite the high seismicity of the New Guinea-Solomon Islands region there is relatively little loss of life due to earthquakes. Partly this is because the typical bush-material village house can collapse with minimum risk of injury. There are no bricks or concrete and no heavy or sharp objects to fall and injure the occupants. Probably the greatest threat to life is from landslides triggered by earthquakes.

Worldwide, the greatest damage and injury from earthquakes occurs in cities where buildings fail, either because they are old buildings that pre-date modern building codes, or because building codes have been ignored. An example is the M6.9 earthquake that struck the city of Bhuj in western India on 26 January 2001 killing 17,000 people and destroying 270,000 buildings. Bhuj had no historical record of strong earthquakes. Another example is the shallow M6.7 earthquake that struck the ancient port city of Bam in southeastern Iran on 26 December 2003 killing 30,000 people and destroying 85 percent of all buildings. These buildings were made of mud brick. In contrast, a stronger earthquake, M7.7, that struck Wewak in the early hours of 9 September 2002 disrupted power and supplies, damaged village houses, and caused landslides, but very few lives were lost.

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (including pictures) and ask questions on earthquake. Teachers can show videos related to earthquake.	Students will use the information provided to answer questions on earthquake.
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Construct models of a seismograph - STEAM	
Teaching Strategies Teachers will provide the criteria and the materials to construct models of a seismograph.	**Learning Strategies** In groups, students read the criteria and follow the steps and use the materials available to create a seismograph.

Recommended Resources:

- Davies, H.L., 2013. Earth Tok 3rd Edition. Alan Caudel & Associates, 231p.
- Internet

Unit 3: Earthquakes and Volcanoes

Content Standard	**12.2.3** Students will be able to understand and explore the processes of earthquakes and volcanoes.
Benchmark	**12.2.3.2** Analyse the process of volcanoes.

Topic 2 : Volcanoes

Learning Objectives:

By the end of this topic, the students will be able to:

- Identify and describe the different groups of volcanic materials.
- Distinguish magma from lava and pyroclastics using the characteristics.
- Describe types of volcano (e.g., cinder cone, composite (strato), shield, caldera, basalt plateau, rift), the volcanoes or extrusive events that produce them, and their effects.
- Identify examples of volcano types found in PNG such as Mt Lamington, Karkar, Manam, Rabaul, Ulawuan, Pago.
- Distinguish among the following volcanic features: shield volcanoes, cinder cones, composite (strato) volcanoes, columnar jointing, volcanic domes, lava plateaus

Essential questions

1. What are the different groups of volcanic materials?
2. What are the characteristics and differences between magma and lava?
3. What are the different types of volcanoes and their effects?
4. What are the different types of volcanoes found in PNG?
5. What are the features of volcanoes?

Vocabulary: Lava, magma, pyroclastic flows, nuee ardent, pillow lava, pahoehoe, cinder cone, composite (strato), shield, basalt plateau

Concepts	Essential Skills	Essential Values and Attitudes
• Volcanic materials • Magma and lava • Types of volcanoes and their effects • Types and history of PNG volcanoes • Volcanic features	• Making generalisations • Reasoning • Comparing and contrasting • Modelling	Open-minded, desire to learn, being responsible, critical

Content Background

1. Volcanic materials 1

Volcanic materials are divided into two main groups: pyroclastic materials and lava flow materials. Below is a list of the various volcanic material definitions describing the general characteristics of those materials, and in some cases explanations on their formation.

Lava flow materials

Aa*:* Aa (pronounced "ah-ah" - a Hawaiian term), is lava that has a rough, jagged, spiny, and generally clinkery surface. In thick aa flows, the rubbly surface of loose clinkers and blocks hides a massive, relatively dense interior.

Block*:* Fragments of lava or rock larger than 64 millimetres in size which form due to the fracturing of viscous lava flow surfaces during flow.

Lava*:* The term used for magma once it has erupted onto the Earth's surface. Molten rock that erupts from a vent or fissure.

Lava flow*:* Stream of molten rock that erupts relatively non-explosively from a volcano and moves slowly downslope. An outpouring of lava onto the land surface from a vent or fissure. Also, a solidified tongue-like or sheet-like body formed by outpouring lava.

Pahoehoe*:* Pahoehoe (pronounced "pah-hoy-hoy" - a Hawaiian term), is a very fluid lava flow, that in solidified form, is characterized by a smooth, billowy, or ropy surfaces.

Pillow Lava*:* Fluid lava erupted or flowing under water may form a special structure called pillow lava. Such structures form when molten lava breaks through the thin walls of underwater tubes, squeezes out like toothpaste, and quickly solidifies as irregular, tongue-like protrusions. This process is repeated countless times, and the resulting protrusions stack one upon another as the lava flow advances underwater. The term pillow comes from the observation that these stacked protrusions are sack- or pillow-shaped in cross section. Typically ranging from less than 30 cm to more than a metre in diameter, each pillow has a glassy outer skin formed by the rapid cooling of the lava by water. Much pillow lava is erupted under relatively high pressure created by the weight of the overlying water; there is little or no explosive interaction between hot lava and cold water. The bulk of the submarine part of a Hawaiian volcano is composed of pillow lavas.

2. Volcanic materials 2

Pyroclastic materials

Agglutinate*:* Cinders, scoria or pumice fragments that have partially welded together to form a cohesive mass. Agglutinate forms when the individual pyroclasts retain a high enough temperature after impact to partially melt together (welding). If the fragment are completely molten after impact, they may begin to flow downhill in what is known as a rootless flow.

Ash (volcanic): Fragments less than 2 millimetres in diameter of lava or rock blasted into the air by volcanic explosions.

Blocks: Fragments of lava or rock larger than 64 millimetres in size that are blasted into the air by volcanic explosions. Blocks are ejected during the eruption in a solid state, while bombs are ejected during the eruption in a semi-solid, or partial molten, condition. Generally, blocks often have an angular appearance, due to the fracturing of solid material during the eruption.

Bombs: Fragments of fluid or partially fluid lava or rock larger than 64 millimetres in size that are blasted into the air by volcanic explosions. Bombs are ejected during the eruption in a semi-solid, or partial molten, condition, while blocks are ejected during the eruption in a solid state. Volcanic bombs undergo widely varying degrees of aerodynamic and/or impact shaping, depending on their fluidity, during the flight through the atmosphere and subsequent impact with the ground. Based on their shapes after they hit the ground, bombs are variously described, in the following graphic terms:

Bread-crust bombs - These are bombs that have had their surface fractured, without breaking the bomb apart. These fractures form in one of two ways. In both cases, the exterior shell of the bomb cools and solidifies, while the interior remains molten or partially molten. Impact with the surface can cause the bomb to flex, thus fracturing the solid surface. Once on the ground, gases in the molten interior begin to expand, causing the solid surface to fracture and expand.

Cow-pie bombs - Also called cow-dung bombs. These are very fluid bombs that are greatly deformed during impact. The fluid nature of the bomb causes the lava to flow outward from the centre of the impact, forming a roughly circular, pancake-shaped bomb.

Fusiform bombs - Also called spindle or almond bombs. These bombs have an elongated form which tapers down at each end, with a relatively smooth surface. Many have an almond shape.

Irregular bombs - These are bombs that have no distinguishing shape, but clearly lack the angular nature common with blocks.

Ribbon bombs - Bombs that have a long flat, ribbon-like form.

Spherical bombs - As the name implies, these are bombs with a spherical or ball-like shape.

Cinders: Cinders are vesicular lava fragments 1 centimetre or larger in diameter. See Scoria.

Lapilli: Fragments of lava or rock between 2 and 64 millimetres in size that are blasted into the air by volcanic explosions.

Pumice: A light-coloured, frothy, vesicular volcanic rock, usually of intermediate and felsic composition, formed by the expansion of gas in erupting lava. Commonly perceived as lumps or fragments of pea size and larger but can also occur abundantly as ash-size particles. Because of its numerous gas bubbles, pumice commonly floats on water.

Pyroclastic: Pertaining to fragmented (clastic) rock material formed by a volcanic explosion or ejection from a volcanic vent. See Tephra.

Reticulite: During the exceptionally high fountaining episodes of some eruptions, an extremely vesicular, feathery light pumice, called reticulite or thread-lace scoria, can form and be carried many kilometres downwind from the high lava fountains. Even though reticulite is the least dense kind of tephra, it does not float on water, because its vesicles are open and interconnected. Consequently, when it falls on water, it becomes easily waterlogged and sinks.

Scoria: A dark to reddish-coloured, scoriaceous, vesicular volcanic rock, usually of mafic composition. Scoria forms when blobs of gas-charged lava are thrown into the air during an eruption and cool in flight, falling as dark volcanic rock containing cavities created by trapped gas bubbles.

Tephra: Solid material of all sizes explosively ejected from a volcano into the atmosphere. Tephra is the general term now used by volcanologists for airborne volcanic ejecta of any size. Historically, however, various terms have been used to describe ejecta of different sizes. Fragmental volcanic products less than 2 mm in diameter are called ash, between 2 and 64 mm in diameter are called lapilli, fragments larger than 64 mm are called blocks if they were ejected during the eruption in a solid state, while bombs are ejected during the eruption in a semi-solid, or partial molten, condition. See Pyroclastic.

Sample of volcanic materials identification worksheet

Texture 1	Texture 2	Composition	Tephra Size	Rock Name	Lava Flow Material	Pyroclastic Material
Aphanitic	Aphanitic	Felsic	< 2 mm	Rhyolite	Pahoehoe	Agglutinate
Porphyritic	Porphyritic	Intermediate	2 – 64 mm	Andesite	Aa	Ash
Glassy	Glassy	Mafic	> 64 mm	Basalt	Aa Clinker	Block
Vesicular	Vesicular	Ultramafic	NA		Block	Bread-crust bomb
Pyroclastic	Pyroclastic				NA	Fusiform bomb
						Irregular bomb
						Lapilli
						Pumice
						Reticulite
						Ribbon bomb
						Scoria
						Spherical bomb

3. Magma and lava

One of the biggest misconceptions regarding volcanism is related to the difference between lava and magma. Both of them are molten rock and they both have to do with volcanoes, so why the distinct names? Well, because although they are, indeed similar, lava and magma are not one and the same thing.

Magma

Figure 1. *Magma*

Magma is a molten rock combined with solids and volatiles (chemicals that have low boiling points) that lies beneath Earth's surface and is known to be present on some natural satellites and other planets as well. Magma may also contain dissolved gas, suspended crystals, and even gas bubbles, besides molten rock. This molten rock mix may collect in magma chambers and feed volcanoes, turning into lava once it surfaces, or it can slowly cool and solidify under the Earth's surface and create an intrusion (or a pluton).

Magma can usually reach temperatures between 700 -1315°C, but, very rarely, it can even go up to 1600°C or as low as 600°C.

Lava

Figure 2*. Lava*

Lava is the name given to the molten rock ejected by volcanoes during eruptions. When it is first expelled through a volcanic vent, the rock is liquid and can reach temperatures between 700-1200°C. While lava is hundreds of thousands of times more viscous than water, it is able to flow great distances before it cools down and solidifies, thanks to its sheer thinning quality.

Lava can be classified in multiple categories, depending on its composition and viscosity. Most types of lava contain mostly silicate minerals, such as olivine, feldspar, mica, amphibole, pyroxene and quartz.

Magma	**Lava**
Magma is the name given to molten rock while it's still under the Earth's surface.	Lava is actually magma after it has erupted – once it reached the surface of the Earth
The temperature of magma usually ranges between 700 and 1315°C.	Lava's temperature usually ranges between 700 and 1200°C.
Magma takes considerably longer to cool underground, allowing the crystals to grow large.	Lava cools much faster than magma, which may lead to part of the melt being unable to crystallise and thus becoming glass.
Magma that cools down slowly under the surface of the earth can form plutonic rocks such as diorite, granite, or gabbro.	When cooling down after the eruption, lava forms volcanic rocks, such as andesite, basalt or rhyolite.
The term "magma" has its origins in Ancient Greek.	The term "lava" has its origins in the Italian language and it is believed to derive from the much older Latin word "labes".

4. Types of volcano and their effects

Four Major Types of Volcanoes

(a) Cinder cone, also known as scoria cone
(b) Shield
(c) Composite, also known as strato
(d) Lava dome

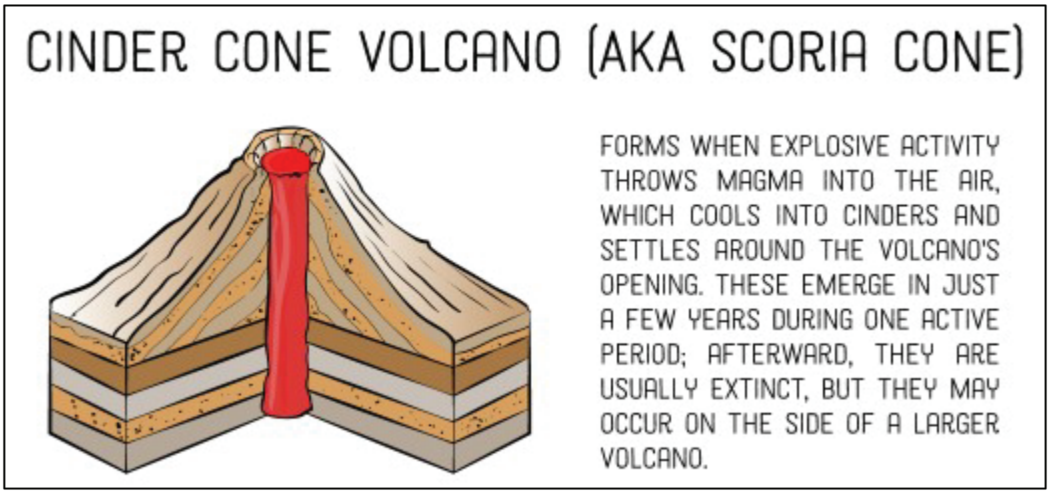
Comparing the shape, height and slope of the different types of volcano

Type of Volcano	Shape	Height	Slope
Cinder cone, also known as Scoria cone	Symmetrical cone	Up to 370 metres	30-40 degrees
Shield	Tall and broad	Up to over 900 metres	Roughly 10 degrees near the base and 5 degrees near the top
Composite, also known as strato	Tall, steep, and symmetrical	Up to 2,400 metres	Roughly 6 degrees near the base and roughly 30 degrees near the top
Lava Dome	Dome	Up to 100 metres	25-30 degrees

Cinder Cone Volcano (also known as Scoria Cone)

One of the most common types of volcanoes is the cinder cone. Less dangerous compared to other types, cinder cones only grow to about 300-365 m tall. Unlike some of the other types of volcanoes - namely, shield volcanoes and composite volcanoes - cinder cones are usually created from a single opening. The opening of a cinder cone is a cone-shaped structure, while the steeps are formed of the erupted, fragmented cinders that fall close to the chimney/vent.

The manner of eruption for cinder cones is relatively simple. When the lava erupts, cinders of it are blown into the air. These fragmented cinders fall a short distance from the opening, thus creating the cone.



CINDER CONE VOLCANO (AKA SCORIA CONE)

FORMS WHEN EXPLOSIVE ACTIVITY THROWS MAGMA INTO THE AIR, WHICH COOLS INTO CINDERS AND SETTLES AROUND THE VOLCANO'S OPENING. THESE EMERGE IN JUST A FEW YEARS DURING ONE ACTIVE PERIOD; AFTERWARD, THEY ARE USUALLY EXTINCT, BUT THEY MAY OCCUR ON THE SIDE OF A LARGER VOLCANO.

Figure 3. *Diagram of cinder cone volcano* (Source: https://owlcation.com/stem/4-Different-Types-of-Volcanoes-Cinder-Cones-Lava-Domes-Shield-and-Composite-Volcanoes)

Lava eruption effects. Cinder cone volcanoes feature highly fluid basaltic lava. However, this lava is thicker toward the top of the magma chamber, causing gasses to become trapped. This produces small explosive outbursts of short durations, known as strombolian eruptions. These lava fountains, driven by expanding gas bubbles, typically shoot 30 to 460 m in the air. The lava breaks up and cools before landing, producing a pile of tephra around the vent. While not considered very dangerous, the falling lava bombs from these eruptions can injure or kill anyone who gets too close.

Lava flow effects. The primary danger from cinder cone volcanoes is lava flows. Once the bulk of the gasses have been released, the eruptions begin to produce large flows of runny lava. These flows typically emerge from either fissures at the base of the volcano or breaches of the crater wall. This is because the loose tephra structure can seldom support the pressure of magma rising to the summit crater and, instead, tends to leak like a sieve. Cinder cones can be very asymmetrical, because prevailing winds blow the falling tephra to one side of the cone. This topography can funnel the lava flows in the opposite direction.

Figure 4. *Effects of lava flow*

Over multiple eruptions, long, fluid lava form broad layers, which accumulate into some of the world's largest volcanoes.

Shield volcano

Another type of volcano is the shield volcano. Unlike cinder cones, shield volcanoes can be very, very big in size. However, they are not as dangerous as that size might make it seem. This is because the eruption of lava out of shield volcanoes is not accompanied by pyroclastic material (bursts of gas and particles).

Shield volcanoes may be tall but tend to be very broad, with less steep slopes than other volcanoes.

Shield volcanoes can be huge because of their ample supply of magma. For example, Mauna Loa in Hawaii is a shield volcano that rises more than 9,100 m above its base on the bottom of the ocean.

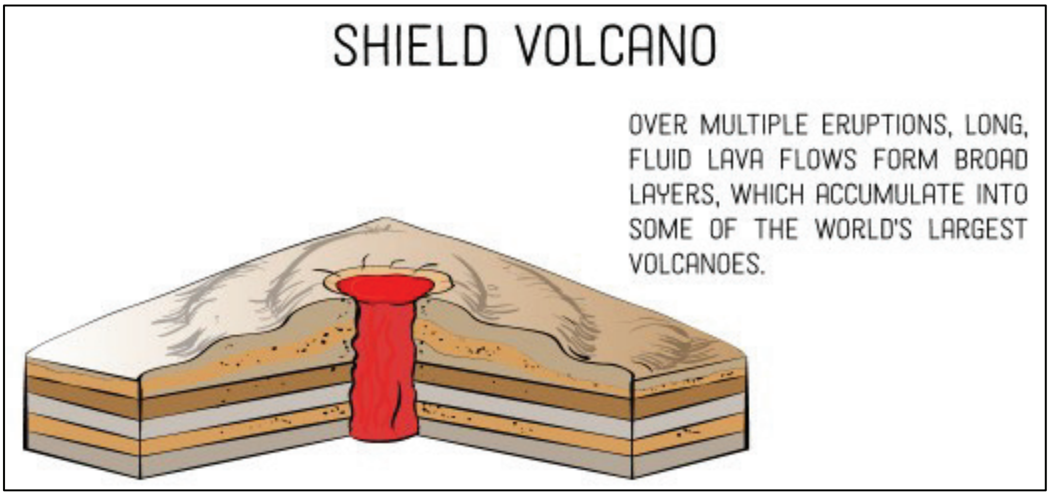


Figure 5. *Diagram of shield volcano* (Source: https://owlcation.com/stem/4-Different-Types-of-Volcanoes-Cinder-Cones-Lava-Domes-Shield-and-Composite-Volcanoes)

Lava flow effects. The lava flow from a shield volcano eruption is largely composed from basaltic magma. The lava features a low viscosity and erupts in a relatively gentle stream. Therefore, shield volcano eruptions generally do not pose a threat to human lives, as the lava flow is easy to predict and avoid. However, in prolonged eruptions, shield volcanoes can produce enough lava flow to reach outlying areas, destroying agriculture, homes and other structures. The lava flow can also reach nearby highways, rendering them impassible.

Figure 6. *Actual image of lava flow*
(Source: https://www.sandatlas.org/types-lava-flows/)

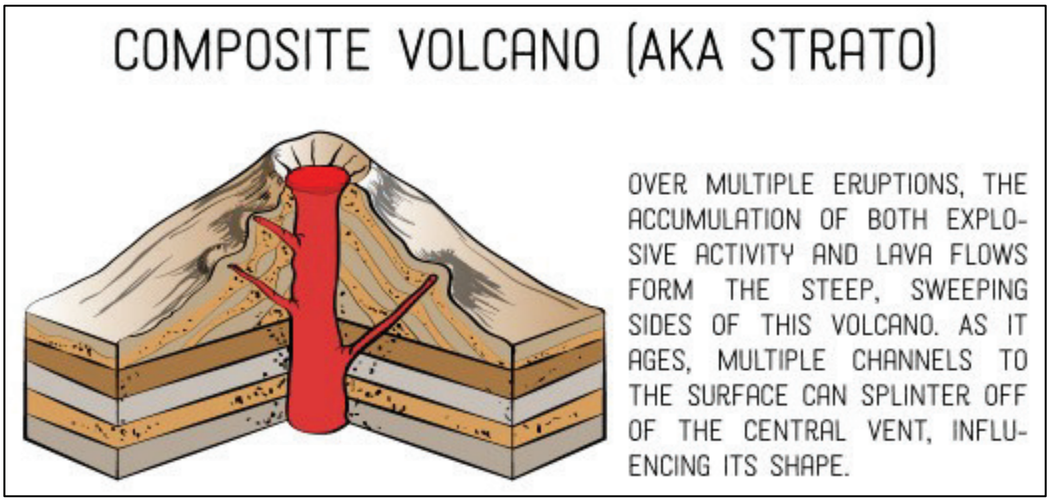
Gasses and debris. Because of the gentle nature of Hawaiian explosions, shield volcanoes produce relatively low amounts of gas and debris. However, sometimes an obstruction in the volcanic vent can cause a buildup of pressure. This leads to a sudden, atypically violent eruption of gas and debris. Therefore, it is dangerous for spectators to be too close to the shield volcano vent, as the eruptive behavior cannot always be predicted. Another negative is, as with all volcanoes, the gases produced by shield volcanoes lend to the greenhouse effect that global warming.

Composite volcanoes

Composite volcanoes are also known as strato volcanoes. Composite volcanoes are reasonably big and can rise up 2430-3048 m. Moreover, they can range anywhere from 1-10 km in diameter. Their eruptions are dangerous and explosive in nature, with many layers of lava and pyroclastic materials, the current of rock and gas that can reach 980°C and 724 km/h, killing any living organism in its path immediately. The citizens of Pompeii were killed by a composite volcano's pyroclastic flow.

The general structure of composite volcanoes is tall and symmetrical and with steep sides. Commonly, composite volcanoes erupt hot gases, ash, lava, and pumice as well as stiff, slow-moving lava. Moreover, deadly mudflows - also commonly known as ‘lahars’ - can also accompany the eruption.

Composite volcanoes are believed to kill the most people because of their deadly nature and high numbers. Apart from their dangerous side, composite volcanoes are also famous because they comprise some of the most beautiful mountains on planet Earth. For example, Mount Fuji of Japan and Mount Shasta in California are two famous composite volcanoes.


COMPOSITE VOLCANO (AKA STRATO)

OVER MULTIPLE ERUPTIONS, THE ACCUMULATION OF BOTH EXPLOSIVE ACTIVITY AND LAVA FLOWS FORM THE STEEP, SWEEPING SIDES OF THIS VOLCANO. AS IT AGES, MULTIPLE CHANNELS TO THE SURFACE CAN SPLINTER OFF OF THE CENTRAL VENT, INFLUENCING ITS SHAPE.

Figure 7. *Diagram of composite volcano* (Source: https://owlcation.com/stem/4-Different-Types-of-Volcanoes-Cinder-Cones-Lava-Domes-Shield-and-Composite-Volcanoes)

Hazards associated with shield volcanoes include: lava flows, airborne ash particles, corrosive volcanic gases, volcanic glass, ground cracks and settling, earthquakes, and explosions caused by the interaction of lava with seawater. Of these hazards, lava flows are the most common.

Lava dome volcano

Lava domes are the fourth type of volcano that we are going to discuss. Unlike composite and shield volcanoes, lava domes are of significantly smaller stature. They are formed when the lava is too viscous to flow to a great distance. As the lava dome slowly grows, the outer surface cools and hardens as the lava continues to pile within. Eventually, the internal pressure can shatter the outer surface, causing loose fragments to spill down its sides. Generally, such lava domes are found on the flanks of larger composite volcanoes.

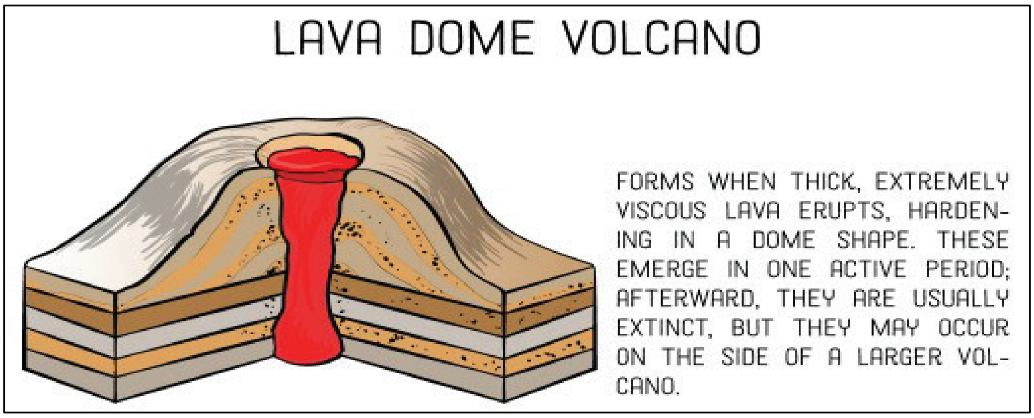


Figure 8. *Diagram of lava dome volcano* (Source: https://owlcation.com/stem/4-Different-Types-of-Volcanoes-Cinder-Cones-Lava-Domes-Shield-and-Composite-Volcanoes)

5. Volcanic Hazards

(a) Primary effects of volcanism

Lava flows - lava flows are common in Hawaiian and Strombolian type of eruptions, the least explosive. Although they have been known to travel as fast as 64 km/hr, most are slower and give people time to move out of the way. Thus, in general, lava flows are most damaging to property, as they can destroy anything in their path.

Pyroclastic flows - Pyroclastic flows are one of the most dangerous aspects of volcanism. They cause death by suffocation and burning. They can travel so rapidly that few humans can escape.

Ash falls - Although tephra falls blanket an area like snow, they are far more destructive because tephra deposits have a density more than twice that of snow and tephra deposits do not melt like snow a cause the collapse of roof. They and can affect areas far from the eruption. Tephra falls destroy vegetation, including crops, and can kill livestock that eat the ash covered vegetation. Tephra falls can cause loss of agricultural activity for years after an eruption.

Poisonous gas emissions – volcanoes can emit poisonous gases, which are harmful to people. Some of these gases are corrosive.

(b) Secondary and tertiary effects of volcanism

Mudflows (lahars) - as discussed above, mudflows can both accompany an eruption and occur many years after an eruption. They are formed when water and loose ash deposits come together and begin to flow. The source of water can be derived by melting of snow or ice during the eruption, emptying of crater lakes during an eruption, or rainfall that takes place any time with no eruption.

Debris avalanches, landslides, and debris flows - volcanic mountains tend to become over steepened because of the addition of new material over time as well due to inflation of the mountain as magma intrudes. Over steepened slopes may become unstable, leading to a sudden slope failure that results in landslides, debris flows or debris avalanches. Debris avalanches, landslides, and debris flows do not necessarily occur accompanied by a volcanic eruption. There are documented cases of such occurrences where no new magma has been erupted.

Flooding - Drainage systems can become blocked by deposition of pyroclastic flows and lava flows. Such blockage may create a temporary dam that could eventually fill with water and fail resulting in floods downstream from the natural dam. Volcanoes in cold climates can melt snow and glacial ice, rapidly releasing water into the drainage system and possibly causing floods. *Jokaulhlaups* occur when heating of a glacier results in rapid outburst of water from the melting glacier.

Tsunami - Debris avalanche events, landslides, caldera collapse events, and pyroclastic flows entering a body of water may generate tsunami. During the 1883 eruption of Krakatau volcano, in the straits of Sunda between Java and Sumatra, Indonesia, several tsunamis were generated by pyroclastic flows entering the sea and by collapse accompanying caldera formation. The tsunami killed about 36,400 people, some as far away from the volcano as 200 km.

Volcanic earthquakes - Earthquakes usually precede and accompany volcanic eruptions, as magma intrudes and moves within the volcano. Although most volcanic earthquakes are small, some are large enough to cause damage in the area immediately surrounding the volcano, and some are large enough to trigger landslides and debris avalanches, such as in the case of Mount St. Helens, Italy.

Atmospheric effects - Fined grained ash and sulphur gases expelled into the atmosphere reflect solar radiations and cause cooling of the atmosphere. CO_2 released by volcanoes can cause warming of the atmosphere.

6. Types and history of PNG volcanoes

All active volcanoes of Papua New Guinea are well known and documented . The country has the most active volcanoes in the Southwest Pacific. The most active volcanoes include Manam, Karkar, Lamington, Langila, Ulawun, Rabaul and Bagana .

The volcanoes of PNG are found in two principal volcanic arcs, the 1000 km long Bismarck Arc stretching WNW-ESE at north of New Guinea and New Britain Island, from the north coast of New Guinea near the border with Indonesia, to Bougainville Island in the east. This arc is a result of the northward subducting Solomon Sea plate beneath the Bismarck Sea plate.

The second volcanic arc forms the volcanoes on the south-eastern peninsula of New Guinea and is caused by the former southwest subduction of the Solomon Sea Plate. However, there is currently no Wadati-Benioff zone, which would otherwise indicate southeastern subduction of the Solomon Sea plate beneath the NE Papuan peninsula.

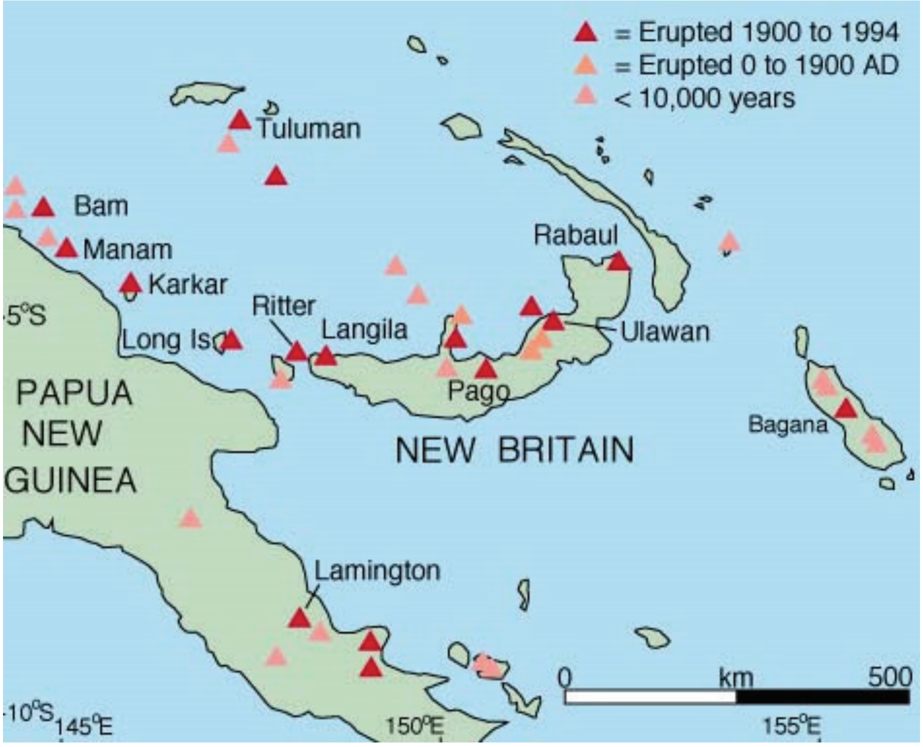


Figure 9. *Map showing the names and locations of volcanoes in PNG* (Source: http://volcano.oregonstate.edu/vwdocs/volc_images/southeast_asia/papua_new_guinea/tectonics.html)

7. Comparing volcanic features

Volcanic processes create many features such as:

- Craters form as the result of explosive eruptive activity at a volcanic vent where rock, magma, and other material is ejected leaving a conical void.

Figure 10. *Image showing calderas volcanic landform*

- Calderas are large-scale landforms that develop after enormous eruptions of magma empty underground magma chamber(s). The volcanic landscape above the void(s) collapses downward and forms the caldera.

Figure 11. *Image showing Diatreme-Maar volcanic landform* (Source: https://volcano.si.edu/volcano)

- Diatreme-Maar volcanic landforms are produced by explosive eruptions that cut into pre-eruption rock and form tephra ring deposits surrounding the crater.

Figure 12. *Image of Devil Mountain Maar, Bering Land Bridge National Preserve, Alaska*

- Lava can flow out of fissures and vents forming a variety of features depending on the composition and viscosity. Learn about the two types of basaltic lava flows: Aa and Pahoehoe.

Figure 13. *Image of Pahoehoe lava and Hawaii Volcanoes National Park, Hawaii. USGS photo*

- Lava tubes are formed as an active lava flow continues to flow beneath its own cooling exterior. The molten lava is insulated in the underground conduit of and continues to drain. The remaining empty passage is called a *lava tube* or *lava cave*.

Figure 14. *Image of Cave entrance at El Malpais National Monument, New Mexico.*

- Fumaroles emit steam and gas in volcanic areas as a result of water that comes into contact with high temperature rock underground.

Figure 15. *Image of Roaring Mountain, Yellowstone National Park.*

- Heat from volcanic activity can create features such as hot springs, geysers, and mud pots.

Figure 16. *Image of hot spring in Rabaul, Papua New Guinea*

Intrusive volcanic features are intruded into the lithosphere or rock, there they cool and solidify into rocks and are later exposed at the land surface as erosion and weathering denudes the land downwards. Most volcanic features are intrusive, most volcanic materials never actually make it to the ground surface in their molten state.

Batholiths are huge scale features where magma is intruded into the ground and cool very slowly, giving coarse grained rocks with large crystals. The outer edge of the magma is in contact with existing rocks, and the heat and pressure change the rock through metamorphosis creating a metamorphic aureole. If magma is squeezed horizontally along bedding planes through layers of existing rock a layer of rock can cool which is known as a *sill*. If magma is squeezed vertically upwards cutting across bedding planes of sedimentary rocks a *dyke* is created.

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (including pictures) and ask questions on volcanoes. Teachers can show videos related to volcanoes.	Students will use the information provided to answer questions on volcanoes.

STEAM Approach

Learning Objective: By the end of the topic, students will be able to;

- Construct models of the different types of volcanoes - STEAM

Teaching Strategies	**Learning Strategies**
Teachers will provide the criteria and the materials to construct models of different types of volcanoes.	In groups, students read the criteria and follow the steps and use the materials available to create different types of volcanoes.

Recommended Resources:

- https://owlcation.com/stem/4-Different-Types-of-Volcanoes-Cinder-Cones-Lava-Domes-Shield-and-Composite-Volcanoes
- Internet

Unit 4: Surface Processes and Groundwater

Content Standard	**12.2.4** Students will be able to understand and explain the processes of weathering and erosion, and the groundwater system.
Benchmark	**12.2.4.1** Compare and distinguish between mechanical and chemical weathering.

Topic 1 : Weathering

Learning Objectives:

By the end of this topic, the students will be able to:

- Distinguish between weathering and erosion.
- Distinguish between mechanical and chemical weathering including weathering by biological organisms.

Essential questions

1. What is mechanical weathering?
2. What is chemical weathering?
3. What is the difference between mechanical and chemical weathering?

Vocabulary: La Weathering, physical weathering, chemical weathering, biological weathering

Concepts	Essential Skills	Essential Values and Attitudes
• Weathering • Mechanical weathering • Chemical weathering • Types of weathered materials	• Making generalisations • Reasoning • Comparing and contrasting • Modelling	Open-minded, desire to learn, being responsible, critical

Content Background

1. Weathering

Weathering is the process of breakdown and alteration of rocks on the Earth's surface by mechanical, chemical or biological processes. Mechanical (physical) weathering includes the splitting of rocks through the action of frost and extreme temperature changes. Chemical weathering includes solution (the dissolved or solid materials by water); carbonation (the dissolving of solid rocks and minerals by a weak carbonic acid formed by the combination of water and the atmospheric carbon dioxide); oxidation (the combination of atmospheric oxygen with rock materials); and hydration (the chemical combination of rock materials with water). Organic (biological) weathering which may involve both mechanical and chemical processes is caused by plants and animals. For example, burrowing animals and plant roots may physically break up rocks; lichens, which can exist on bare rock surfaces, cause decomposition through the removal of nutrients.

Mechanical weathering

The important agents of mechanical weathering are:

- The decrease in pressure that results from removal of overlying rock
- Freezing and thawing of water in cracks in the rock
- Formation of salt crystals within the rock
- Cracking from plant roots and exposure by burrowing animals

When a mass of rock is exposed by weathering and removal of the overlying rock, there is a decrease in the confining pressure on the rock, and the rock expands. This unloading promotes cracking of the rock, known as exfoliation, as shown in the granitic rock (Fig. 1).

Figure 1. *Exfoliation fractures in granitic rock exposed on the west side of the Coquihalla Highway north of Hope, British Colombia, Canada.*

Frost wedging is the process by which water seeps into cracks in a rock, expands on freezing, and thus enlarges the cracks (Fig. 2). The effectiveness of frost wedging is related to the frequency of freezing and thawing. Frost wedging is most effective in a climate like Canada's. In warm areas where freezing is infrequent, in very cold areas where thawing is infrequent, or in very dry areas, where there is little water to seep into cracks, the role of frost

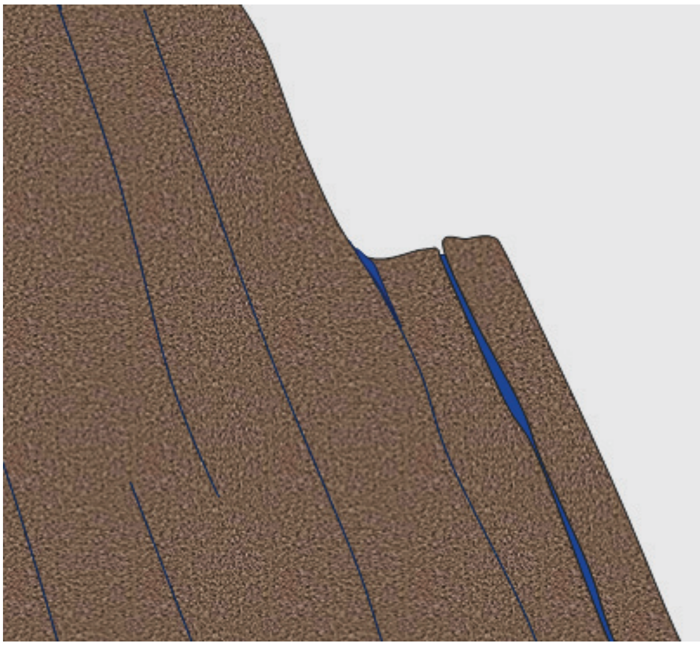


Figure 2. *The process of frost wedging on a steep slope. Water gets into fractures and then freezes, expanding the fracture a little. When the water thaws it seems a little farther into the expanded crack. The process is repeated many times, and eventually a piece of rock will be wedged away* (Source: https://opentextbc.ca/geology/chapter/5-1-mechanical-weathering/)

The effects of plants and animals are significant in mechanical weathering. Roots can force their way into even the tiniest cracks, and then they exert tremendous pressure on the rocks as they grow, widening the cracks and breaking the rock (Fig. 3). Although animals do not normally burrow through solid rock, they can excavate and remove huge volumes of soil, and thus expose the rock to weathering by other mechanisms.

Figure 3. *Conifers growing on granitic rocks at The Lions, near Vancouver, British Colombia, Canada.*

Mechanical weathering is greatly facilitated by erosion, which is the removal of weathering products, allowing for the exposure of more rock for weathering. On the steep rock faces at the top of the cliff, rock fragments have been broken off by ice wedging, and then removed by gravity. This is a form of mass wasting.

Chemical Weathering

Chemical weathering results from chemical changes to minerals that become unstable when they are exposed to surface conditions. The kinds of changes that take place are highly specific to the mineral and the environmental conditions. Some minerals, like quartz, are virtually unaffected by chemical weathering, while others, like feldspar, are easily altered. In general, the degree of chemical weathering is greatest in warm and wet climates, and least in cold and dry climates. The important characteristics of surface conditions that lead to chemical weathering are the presence of water (in the air and on the ground surface), the abundance of oxygen, and the presence of carbon dioxide, which produces weak carbonic acid when combined with water. That process, which is fundamental to most chemical weathering, can be shown as follows:

$H_2O + CO_2$ —-> H_2CO_3 then H_2CO_3 —-> $H^+ + HCO^{3-}$,

water + carbon dioxide —-> carbonic acid then carbonic acid —-> hydrogen ion + carbonate ion

There are two main types of chemical weathering. On the one hand, some minerals become altered to other minerals. For example, feldspar is altered by hydrolysis to clay minerals. On the other hand, some minerals dissolve completely, and their components go into solution. For example, calcite ($CaCO_3$) is soluble in acidic solutions.

The hydrolysis of feldspar can be written like this:

$CaAl_2Si_2O_8 + H_2CO_3 + ½O_2$ —-> $Al_2Si_2O_5(OH)_4 + Ca^{2+} + CO_3^{2-}$
plagioclase + carbonic acid —-> kaolinite + dissolved calcium + carbonate ions

Oxidation is another very important chemical weathering process. The oxidation of the iron in a ferromagnesian silicate starts with the dissolution of the iron. For olivine, the process looks like this, where olivine in the presence of carbonic acid is converted to dissolved iron, carbonate, and silicic acid:

$Fe_2SiO_4 + 4H_2CO_3$ —> $2Fe^{2+} + 4HCO^{3-} + H_4SiO_4$

Olivine + (carbonic acid) —> dissolved iron + dissolved carbonate + dissolved silicic acid

In the presence of oxygen, the dissolved iron is then quickly converted to hematite:

$2Fe^{2+} + {}_4HCO^{3-} + ½\ O_2 + 2H_2O$ —->$Fe_2O_3 + 4H_2CO_3$

Dissolved iron + bicarbonate + oxygen + water—->hematite + carbonic acid

The **hydrolysis** of feldspar and other silicate minerals and the oxidation of iron in ferromagnesian silicates all serve to create rocks that are softer and weaker than they were to begin with, and thus more susceptible to mechanical weathering.

The weathering reactions that we've discussed so far involved the transformation of one mineral to another mineral (e.g., feldspar to clay), and the release of some ions in solution (e.g., Ca2+). Some weathering processes involve the complete dissolution of a mineral. Calcite, for example, will dissolve in weak acid, to produce calcium and bicarbonate ions. The equation is as follows:

$CaCO_3 + H^+ + HCO^{3-}$ ––> $Ca^{2+} + 2HCO^{3-}$

Calcite + hydrogen ions + bicarbonate ––> calcium ions + bicarbonate

The three common chemical reactions associated with chemical weathering are dissolution, hydrolysis, and oxidation.

Biological weathering

Organic - Cracking of rocks by plant roots and burrowing animals, etc.

2. Types of weathered materials

When rocks are exposed at the Earth's surface they are attacked by weathering and erosion. This produces three kinds of material:

- Fragments or detritus broken from rocks by erosion
- New minerals such as clays formed by weathering of the exposed rocks; and
- Material in solution.

Fragments or detritus broken from the exposed rocks

Detritus are the pieces of rock broken off by ice, glacier or erosion; or organic waste material from decomposing dead plants or animals; or debris or fragments of disintegrated material. Loose gravel, silt, sand, and decomposed organic matter such as piles of dead leaves can all be called detritus.

New minerals such as clays formed by weathering of the exposed rocks

Clay minerals are very small particles, chiefly hydrous silicates of aluminium and/or iron substituting for all or part of the aluminium, that are the major constituents of clay materials. The particles are essentially crystalline (either platy or fibrous) with a layered structure, but may be amorphous or metalloidal. The clay minerals are responsible for the plastic properties of clay; the particles have the property of holding water. The chief groups of clay minerals are: kaolinite; halloysite; illite; montmorillonite (formed chiefly through alteration of volcanic ash); and vermiculite (used as an insulating material and potting soil.

Material in solution

As weathering proceeds, the ferromagnesian silicates and feldspar are very likely to be broken into smaller pieces and converted into clay minerals and the material in solution or dissolved ions (e.g.: Ca^{2+}, Na^+, K^+, Fe^{2+}, Mg^{2+}, and H_4SiO_4).

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (including pictures) and ask questions on weathering. Teachers can show videos related to weathering.	Students will use the information provided to answer questions on weathering.

STEAM Approach

Learning Objective: By the end of the topic, students will be able to;

- Construct models of showing how physical and chemical weathering occur in the physical environment - STEAM

Teaching Strategies	Learning Strategies
Teachers will provide the criteria and the materials to construct models showing how physical weathering and chemical weathering occur in the physical environment.	In groups, students read the criteria and follow the steps and use the materials available to create models of how physical weathering and chemical weathering occur in the physical environment.

Recommended Resources:

- Internet

Unit 4: Surface Processes and Groundwater

Content Standard	**12.2.4** Students will be able to understand and explain the processes of weathering and erosion, and the groundwater system.
Benchmark	**12.2.4.2** Analyse the types and causes of soil erosion.
Topic 2 : Erosion	

Learning Objectives:

By the end of this topic, the students will be able to:

- Describe the different agents of soil erosion.
- Identify and describe the different types of soil erosion.
- Explain the causes of the different types of soil erosion.
- Explain the different erosional features.

Essential questions

1. What are the agents of erosion?
2. What are the different types of soil erosion?
3. What are the causes of soil erosion?
4. How are erosions different in terms of their features?

Vocabulary: Erosion, soil erosion

Concepts	Essential Skills	Essential Values and Attitudes
• Erosion • Types of soil erosion • Causes of soil erosion • Erosion and its features	• Making generalisations • Reasoning • comparing and contrasting • Modelling	Open-minded, desire to learn, optimistic, critical

Content Background

1. Erosion

Erosion is the wearing away of the land surface by natural agents that involves the transport of rock debris. The natural agents of erosion include moving water (e.g. rivers, ocean waves), ice (e.g. glacier), wind, organisms, and gravity.

2. Types of soil erosion

Moving water erosion

Flowing water can erode rocks and soil. Water dissolves minerals from rocks and carries the ions. This process happens really slowly. But over millions of years, flowing water dissolves massive amounts of rocks. Moving water erosion can be in the form of raindrop splashing on Earth, waves hitting shoreline, and so on.

- **Splash erosion**
  Rainfall can cause erosion both when the rain hits the surface of Earth, called splash erosion, and when raindrops accumulate like small streams.
- **River erosion**
  Rivers erode in four ways: *Abrasion or corrasion* – this is when large pieces of bedload material wear away the river banks and bed. *Attrition* – this is when the bedload itself is eroded when sediment particles knock against the bed or each other and break, becoming more rounder and smaller. *Hydraulic action* – this is when the force of water erodes softer rock. *Solution or corrosion* – this is when acidic water erodes rock.
- **Wave erosion**
  Water waves also cause erosion (Fig. 1). The rate of erosion of water banks or coast depends on the wave energy. Wave and tidal energy is dissipated at the coastline. If the coastline is hilly or steep, rocky headlands Wave erosion creates landforms such sea cliffs,

Figure 1. *Image of wave erosion*
(Source: https://pixabay.com/photos/rock-sea-waves-erosion-geology-2550146/)

The power of ocean modifies landforms by erosion and deposition. The cliff is being eroded by incoming waves. The beach is being created as sand is being deposited. Differential erosion produced the land feature in the figure above.

Wind erosion

Wind erosion is a natural process that moves soil from one location to another by wind power. It can cause significant economic and environmental damage. Not only does wind erosion damage the land by drying out soil and reducing the nutrients of the land, it can also cause air pollution. Enveloping crops, covering highways, and invading homes, the sand, dust and dirt created from wind erosion can impact plant and human life in numerous ways.

Erosion by gravity

Gravitational erosion describes the movement of soil or rock due to the force of gravity. Gravity impacts erosion in direct ways like landslides, mudslides and slumps. It can also impact erosion in indirect ways, by pulling rain to the Earth and forcing glaciers downhill.

Erosion by glacier

There are three main types of glacial erosion – *plucking*, *abrasion* and *freeze thaw*.

Figure 2. *Franz Josef Glacier (Kā Roimata o Hine Hukatere). Credit: B Lehmann, University of Lausanne, Switzerland* (Source: http://www.geologypage.com/2015/10/scientists-find-formula-for-rate-of-glacial-erosion.html**)**

Plucking is when melt water from a glacier freezes around lumps of cracked and broken rock. When the ice moves downhill, rock is plucked from the back wall. Abrasion is when rock frozen to the base and the back of the glacier scrapes the bed rock. Freeze-thaw is when melt water or rain gets into cracks in the bed rock, usually the back wall. At night the water freezes, expands and causes the crack to get larger. Eventually the rock will break away.

3. Causes of soil erosion

The agents of soil erosion are the same as the agents of all types of erosion: water, wind, ice, or gravity. Running water is the leading cause of soil erosion, because water is abundant and has a lot of power. Wind is also a leading cause of soil erosion because wind can pick up soil and blow it far away.

Activities that remove vegetation, disturb the ground, or allow the ground to dry are activities that increase erosion.

Farming

Agriculture is probably the most significant activity that accelerates soil erosion because of the amount of land that is farmed and how much farming practices disturb the ground (Fig. 3). Farmers remove native vegetation and then plow the land to plant new seeds. Because most crops grow only in spring and summer, the land lies fallow during the winter. Of course, winter is also the stormy season in many locations, so wind and rain are available to wash soil away. Tractor tires make deep grooves, which are natural pathways for water. Fine soil is blown away by wind.

The soil that is most likely to erode is the nutrient-rich topsoil, which degrades the farmland.

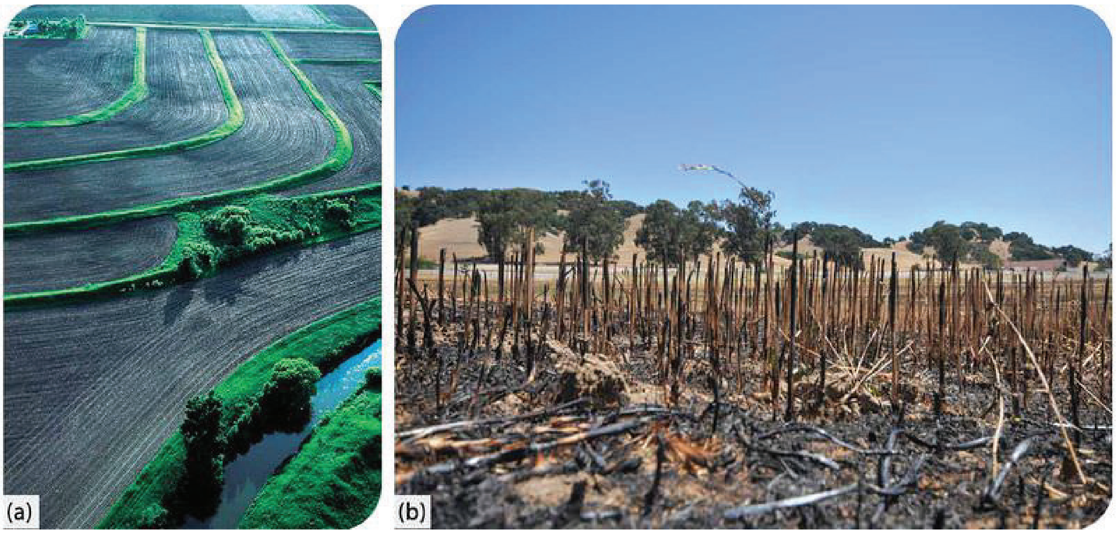


Figure 3. *(a) The bare areas of farmland are especially vulnerable to erosion. (b) Slash-and-burn agriculture leaves land open for soil erosion and is one of the leading causes of soil erosion in the world.* (Source: https://courses.lumenlearning.com/geo/chapter/reading-causes-of-soil-erosion/)

Logging and mining

Logging removes trees that protect the ground from soil erosion. The tree roots hold the soil together and the tree canopy protects the soil from hard falling rain. Logging results in the loss of leaf litter, or dead leaves, bark, and branches on the forest floor. Leaf litter plays an important role in protecting forest soils from erosion.

Figure 4. *Logging exposes large areas of land to erosion* (Source: https://giantdevelopmentinc.com/durham/forestry-services)

Much of the world's original forests have been logged. Many of the tropical forests that remain are currently the site of logging because North America and Europe have already harvested many of their trees (Fig. 4). Soils eroded from logged forests clog rivers and lakes, fill estuaries, and bury coral reefs.

Although soil erosion is a natural process, human activities have greatly accelerated it. The agents of soil erosion are the same as of other types of erosion: water, ice, wind, and gravity. Soil erosion is more likely where the ground has been disturbed by agriculture, grazing animals, logging, mining, construction, and recreational activities.

4. Differential erosion and its features

Differential erosion is erosion that occurs at irregular or varying rates, caused by the differences in the resistance and hardness of surface materials whereby the softer and weaker rocks are rapidly worn away, whereas the harder and more resistant rocks remain to form ridges, hills, or mountains (Fig. 5). Differential erosion can be caused by any agent of erosion (wind, water, etc).

Figure 5. *Some geological features produced due to differential erosion.*

Teaching and Learning Strategies

<table>
<tr><th>Teaching Strategies:</th><th>Learning Strategies</th></tr>
<tr><td>Teachers prepare information (including pictures) and ask questions on erosion. Teachers can show videos related to erosion.</td><td>Students will use the information provided to answer questions on erosion.</td></tr>
<tr><td colspan="2">STEAM Approach
Learning Objective: By the end of the topic, students will be able to;
• Construct models of showing different types of erosion occur in the physical environment - STEAM</td></tr>
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Teachers will provide the criteria and the materials to construct models showing how different types of erosion occur in the physical environment.</td><td>Learning Strategies
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<tr><td colspan="2">Recommended Resources:
• Internet</td></tr>
</table>

Unit 4: Surface Processes and Groundwater

Content Standard	**12.2.4** Students will be able to understand and explain the processes of weathering and erosion, and the groundwater system.
Benchmark	**12.2.4.3** Compare and distinguish between erosional and depositional features.

Topic 3 : Stream Erosion and Deposition

Learning Objectives:

By the end of this topic, the students will be able to:

- Differentiate between erosional and depositional features formed by glaciers, running water, wind, and wave action.
- Explain the processes (e.g. abrasion, dissolution) by which glaciers, running water, wind, and wave action erode rock and sediment.
- Relate factors such as load, gradient, discharge, channel shape, sediment composition, and human activities to erosion and deposition by (e.g. streams, rivers)

Essential questions

1. What is stream erosion?
2. How does stream erosion occur?
3. What are the types of sediments in streams?
4. Where do streams deposit the sediments?
5. What types of depositional environment are there?

Vocabulary: Stream erosion, deposition, abrasion, attrition, hydraulic action, dissolution

Concepts	Essential Skills	Essential Values and Attitudes
• Types of stream erosion • Abrasion and dissolution • Sediment transportation by river • Depositional environments	• Making generalisations • Reasoning • Comparing and contrasting • Modelling	Open-minded, desire to learn, optimistic, critical

Content Background

1. Steam Erosion

Types of stream erosion

Streams are one of the most effective surface agents that erode rock and sediment. Erosional landscapes such as the Grand Canyon have been formed by constant erosion from running water over millions of years. In addition to eroding the bedrock and previously deposited sediments along its route, a stream constantly abrades and weathers the individual rock and soil particles carried by its water. Hydraulic action, abrasion, and solution are the three main ways that streams erode the earth's surface.

Hydraulic action. The ability of flowing water to dislodge and transport rock particles or sediment is called hydraulic action. In general, the greater the velocity of the water and the steeper the grade, the greater the hydraulic action capabilities of the stream. Hydraulic action is also enhanced by a rough and irregular stream bottom, which offers edges that can be “grabbed” by the current and that create uplifting eddies.

Abrasion. Abrasion is the process by which a stream's irregular bed is smoothed by the constant friction and scouring impact of rock fragments, gravel, and sediment carried in the water. The individual particles of sediment also collide as they are transported, breaking them down into smaller particles. Generally the more sediment that a stream carries, the greater the amount of erosion of the stream's bed. The heavier, coarser-grained sediment strikes the stream bed more frequently and with more force than the smaller particles, resulting in an increased rate of erosion.

Circular depressions eroded into the bedrock of a stream by abrasive sediments are called potholes. The scouring action is greatest during flood conditions. Potholes are found where the rock is softer or in locations where the flow is channelled more narrowly, such as between or around boulders.

Solution. Rocks susceptible to the chemical weathering process of solution can be dissolved by the slightly acidic water of a stream. Limestones and sedimentary rock cemented with calcite are vulnerable to solution. The dissolution of the calcite cement frees the sedimentary particles, which can then be picked up by the stream's flow through hydraulic action.

Transportation

Transportation of material in a river begins when friction is overcome. Material that has been loosened by erosion may be then transported along the river. There are four main processes of transportation. These are:

(a) suspension / suspended load;
(b) solution / solution load;
(c) saltation; and
(d) traction.

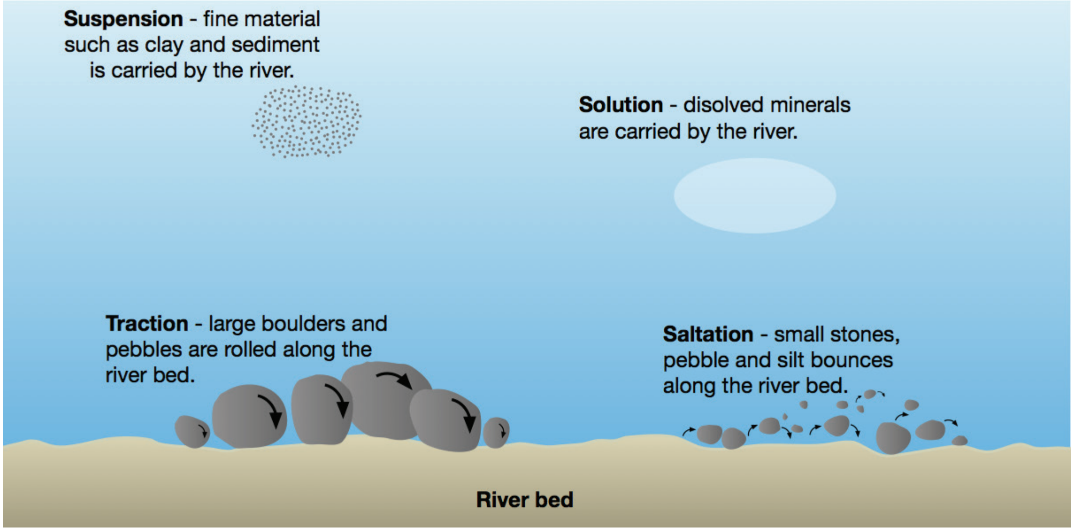

Figure 1: *Processes of transportation in a river* (Source: https://www.alevelgeography.com/the-long-profile-changing-processes-types-of-erosion-transportation-and-deposition/)

Suspension is when material made up of very fine particles such as clay and silt is lifted as the result of turbulence and transported by the river. Faster-flowing, turbulent rivers carry more suspended material. This is why river appear muddy as they are approaching bankfull discharge and towards the mouth of the river (where velocity is greater as is the occurrence of finer sediment).

Solution is when dissolved material is carried by a river. This often happens in areas where the geology is limestone and is dissolved in slightly acidic water.

Saltation is when material such as pebbles and gravel that is too heavy to be carried in suspension is bounced along the river by the force of the water.

Traction is when large materials such as boulders are rolled and pushed along the river bed by the force of the river.

2. Abrasion and dissolution

Abrasion is another form of physical weathering that causes rock to deteriorate over time. Abrasion is the reason that rocks on a riverbed are typically smooth and rounded. As water in the stream flows, it causes rocks to collide with one another, wearing off any rough edges. Wind can also aid in abrasion. Tiny particles of dust and rock in the wind can collide with exposed rock, smoothing down rock faces over millions of years.

Dissolution is the most easily observed kind of chemical weathering. Over time, the action of slightly acidic solutions on the rock can leave pits and holes, and it can act to slowly enlarge and widen pre-existing fractures. On a large scale, dissolution can result in a very distinct type of topography- karst topography. Such areas can feature sinkholes, springs, caves, caverns and other features related to the dissolution of underlying bedrock.

Figure 2. *This photo, of the Ohio Caverns, shows the results of large-scale dissolution as water flowed through subsurface limestone.*
(Source: http://www.panoramio.com/photo/22535678)

3. Sediment transportation by river

Flowing water is a very important mechanism for both erosion and deposition. Water flow in a stream is primarily related to the stream's gradient, but it is also controlled by the geometry of the stream channel. Water flow velocity is decreased by friction along the stream bed, so it is slowest at the bottom and edges and fastest near the surface and in the middle. In fact, the velocity just below the surface is typically a little higher than right at the surface because of friction between the water and the air. On a curved section of a stream, flow is fastest on the outside and slowest on the inside.

Large sediment particles rest on the bottom and may only be moved during rapid flows under flood conditions by saltation and by traction. Smaller particles may rest on the bottom some of the time, where they can be moved by saltation and traction, but they can also be held in suspension in the flowing water, especially at higher velocities. Streams that flow fast tend to be turbulent and the water may be muddy, while those that flow more slowly tend to have laminar flow and clear water. Turbulent flow is more effective than laminar flow at keeping sediments in suspension. Stream water also has a dissolved load, which represents (on average) about 15% of the mass of material transported, and includes ions such as calcium (Ca^{+2}) and chloride (Cl^{-}) in solution. The solubility of these ions is not affected by flow velocity. The faster the water is flowing, the larger the particles that can be kept in suspension and transported within the flowing water.

A stream typically reaches its greatest velocity when it is close to flooding over its banks. This is known as the bank-full stage. As soon as the flooding stream over tops its banks and occupies the wide area of its flood plain, the water has a much larger area to flow through and the velocity drops significantly. At this point, sediment that was being carried by the high-velocity water is deposited near the edge of the channel, forming a natural bank or levée.

4. Depositional environments

Erosion (transport of sediment) usually ends with the deposition of sediments (and soil). Deposition occurs when the forces responsible for erosion are no longer sufficient to transport the sediment. There are a wide variety of environments on the Earth's surface where the deposition of sediments occurs as the result of fluvial (rivers), aeolian (wind) and glacial (ice) erosion.

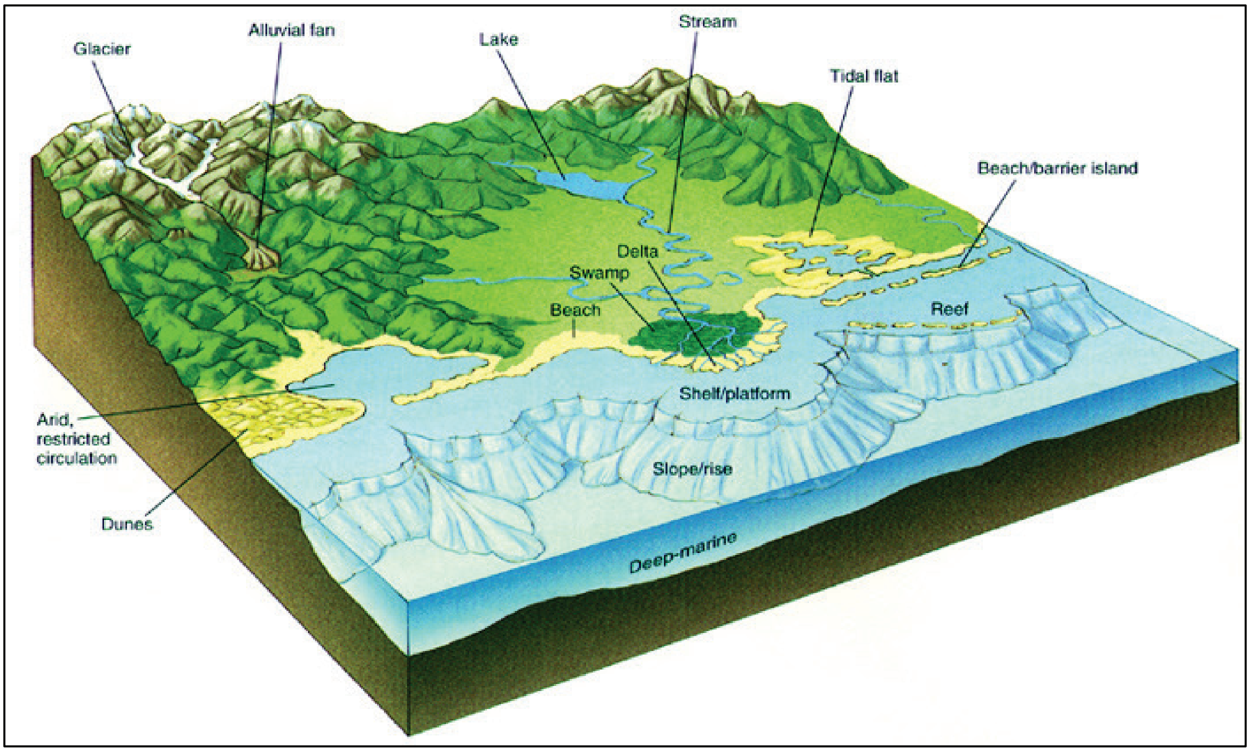

Figure 3. *This is a schematic diagram showing the main sedimentary depositional environments* (Source: https://www3.nd.edu/~cneal/planetearth/Lab-Sedimentary/index.html)

Transported sediments can be deposited in basins, rivers and deltas, shoreline and near-shore, offshore deep water and deserts.

Basin

A sedimentary basin is an area of the Earth's crust that has been subjected to progressive sinking, and where sediments from the erosion of the rocks around it accumulate.

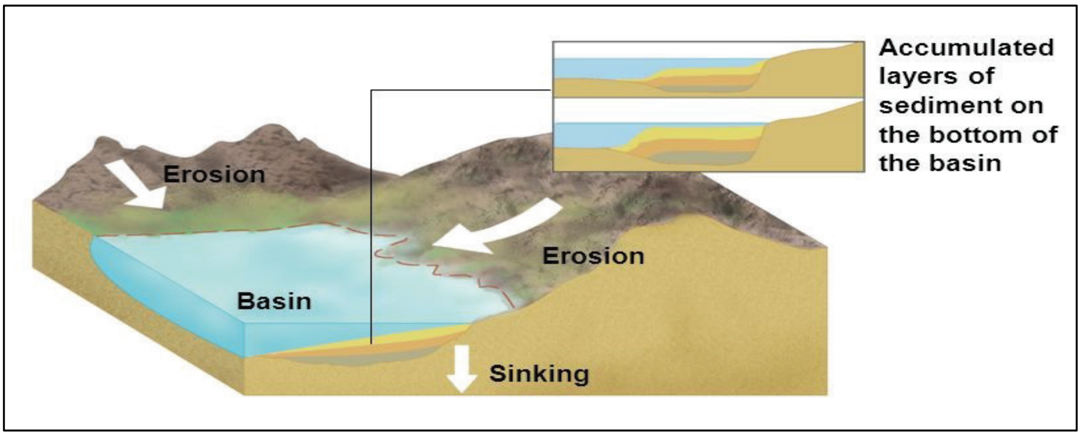

Figure 4. *Schematic of a sedimentary basin*
(Source: http://basins.ghkates.com/what-is-a-sedimentary-basin/)

Note! The term *basin* is used both for topographic depression currently receiving sediment, and in the historic sense, for an area of past sedimentation that is not necessarily still receiving sediment. Thus, Papuan basin refers to the area of past sedimentation that is now above sea level in Western and Central Papua.

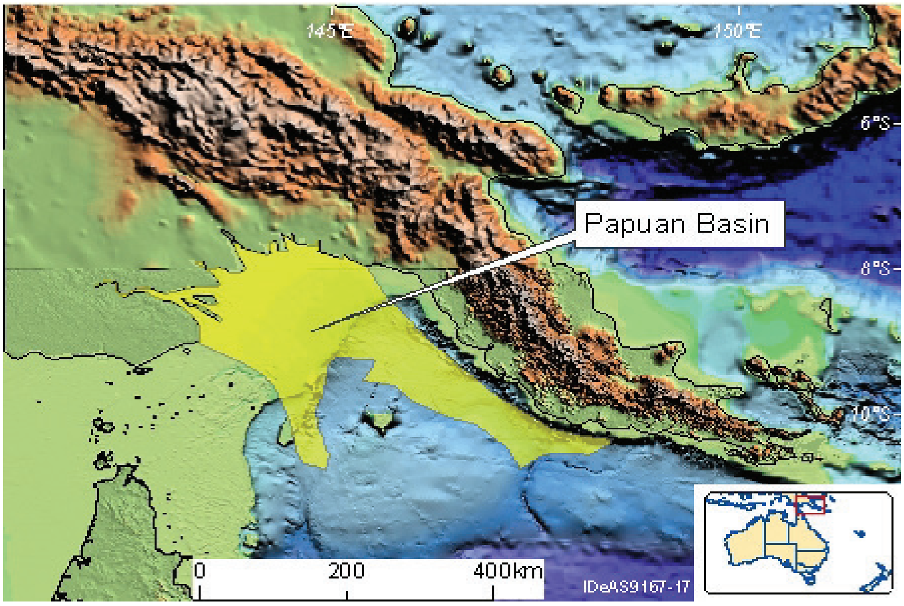

Figure 5. *Map showing the location of the Papuan Basin in relation to Australia*
(From Geoscience Australia)

Papua New Guinea has five major sedimentary basins. Of these, the Papuan Basin has the highest number of wells drilled. The Papuan basin to date has over 200 wells drilled. The success rate is quite high in terms of oil and gas exploration. The other sedimentary basins are quite prolific too and comprised of North New Guinea which has over 20 wells drilled, Cape Vogel Basin has 5 wells drilled, Bougainville Basin has 1 well, and New Ireland Basin has yet to have a well drilled.

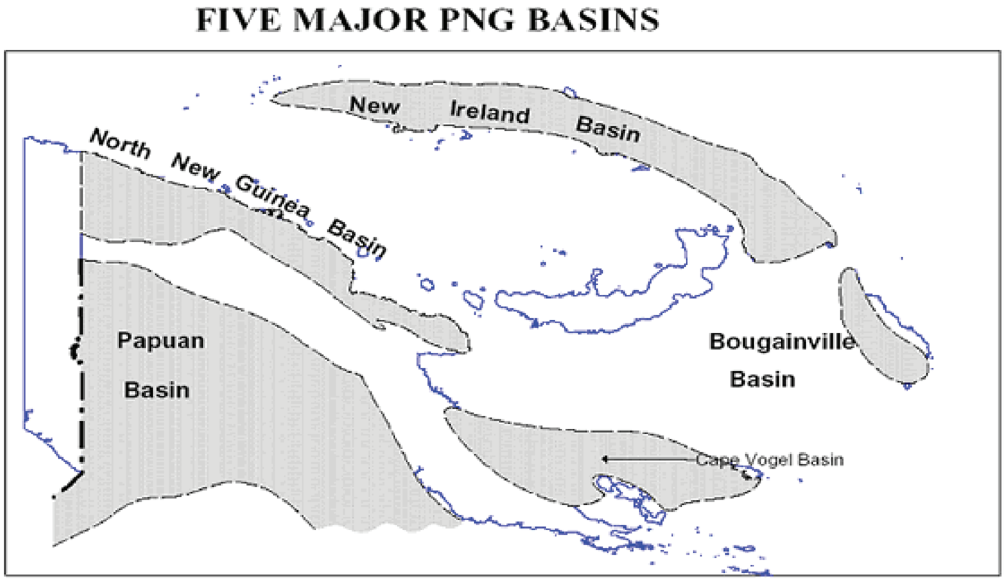

Figure 6. *The maps show the location of the five major basins of Papua New Guinea* (From PNG Department of Petroleum and Energy).

Teaching and Learning Strategies

<table>
<tr><th>Teaching Strategies:</th><th>Learning Strategies</th></tr>
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• Internet</td></tr>
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Unit 4: Surface Processes and Groundwater

Content Standard	**12.2.4** Students will be able to understand and explain the processes of weathering and erosion, and the groundwater system.
Benchmark	**12.2.4.4** Analyse the types and causes of mass wasting.

Topic 4: Mass Movement

Learning Objectives:
By the end of this topic, the students will be able to:

- Identify and explain the different types of mass movements.
- Describe the different types of submarine mass movement.
- Explain how mass movements are deposited.
- Describe the causes of different mass movement.
- Explain the different methods of controlling mass movement.

Essential questions

1. What is mass movement?
2. What are the different types of mass movement?
3. What are the products of mass movement?
4. What is submarine mass movement?
5. How can mass movement be prevented?

Vocabulary: Mass movement

Concepts	Essential Skills	Essential Values and Attitudes
• Types of mass movement • Types of submarine mass movement • Deposits from mass movement • Causes of mass movement • Mass movement controls	• Making generalisations • Reasoning • Analysing • comparing and contrasting	Open-minded, desire to learn, optimistic, critical

Content Background

1. Types of mass movement

Mass movement (or mass wasting) is the downslope motion of rock, regolith (soil, sediment, and debris), snow, and ice. Erosion and mass wasting appear to be similar processes but have distinctly different causes. The movement of sediment by erosion requires mobile agents such a water, wind, and ice. That is, the sediment is transported by the movement of the agents.

Mass wasting (commonly referred to as landslides) involves the transfer of rock and soil downslope under the influence of gravity. Gravity is the key factor in mass wasting and the movement of material does not require a mobile agent.

There are five types of mass movements.

(a) Rockfalls
(b) Slides
(c) Slumps
(d) Flows
(e) Creep

These types of mass movements are broken down into different groups due to difference in material, speed, and distance.

Different types of mass movement based on four factors:

(a) Type of material involved (rock, regolith, snow, ice);
(b) Velocity of the movement (slow, intermediate, fast);
(c) Character of the movement (chaotic cloud, slurry, coherent mass)
(d) Environment (subaerial, submarine)

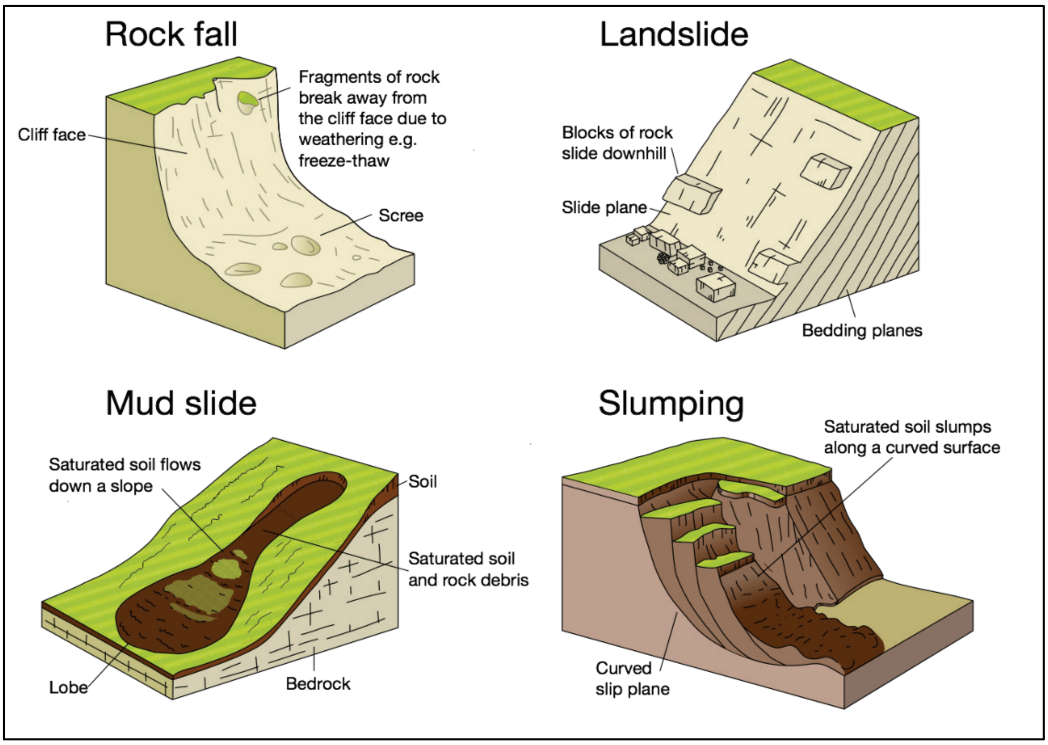


Figure 1. *Types of mass movement* (Source: https://www.internetgeography.net/topics/what-is-mass-movement/)

Slumping

Cliffs formed from boulder clay, material deposited by glacial periods, are susceptible to high rates of coastal erosion. The Holderness Coast is an example of a coastline formed from boulder clay and is the fastest eroding coastline in Europe. The soft boulder clay is quickly eroded through hydraulic action and abrasion. However, this is not the only way it is being eroded. Sub-aerial processes, such as rainfall, also cause erosion. This often happens where layers of boulder clay, left behind by melting glaciers, become saturated and cause the cliff to slump. The debris on the beach is then eroded by the sea leaving the cliff exposed once more.

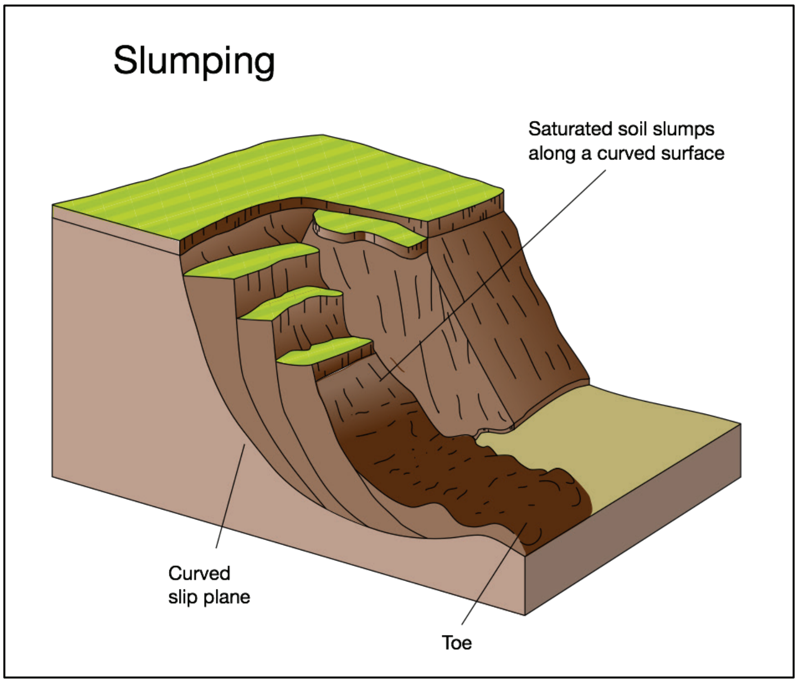


Figure 2. *An annotated diagram showing the main features of slumping.*

Landslides

In areas of more resistant cliff material erosion is greatest when waves break at the foot of a cliff. This causes erosion at the base of the cliff. This creates a wave-cut notch in the base of the cliff. As the notch increases in size, the weight of the cliffs above become too much to support which leads to a landslide. This material will provide temporary protection for the cliff behind. However, once it has been removed by the sea this process will occur again. Where cliffs are made of more resistant material, wave-cut platforms will be created.

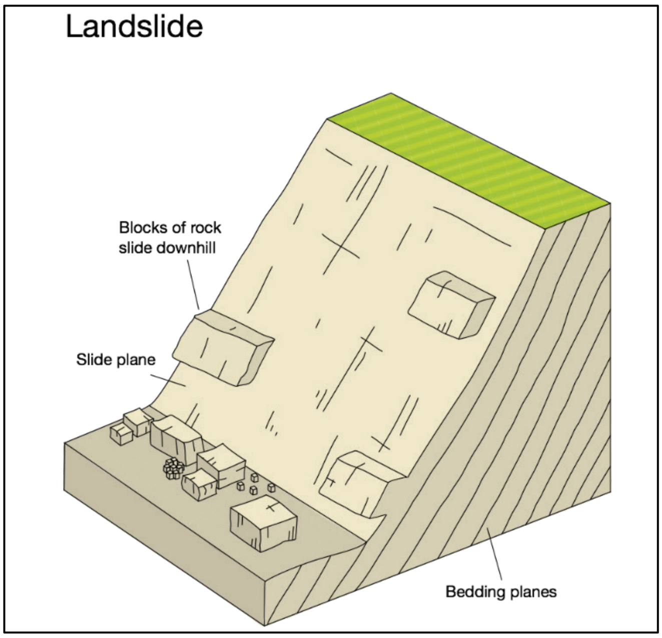


Figure 3. *An annotated diagram showing the main features of a landslide.*

Rockfall

A rockfall involves fragments of rock breaking away from the cliff face, often due to freeze-thaw weathering.

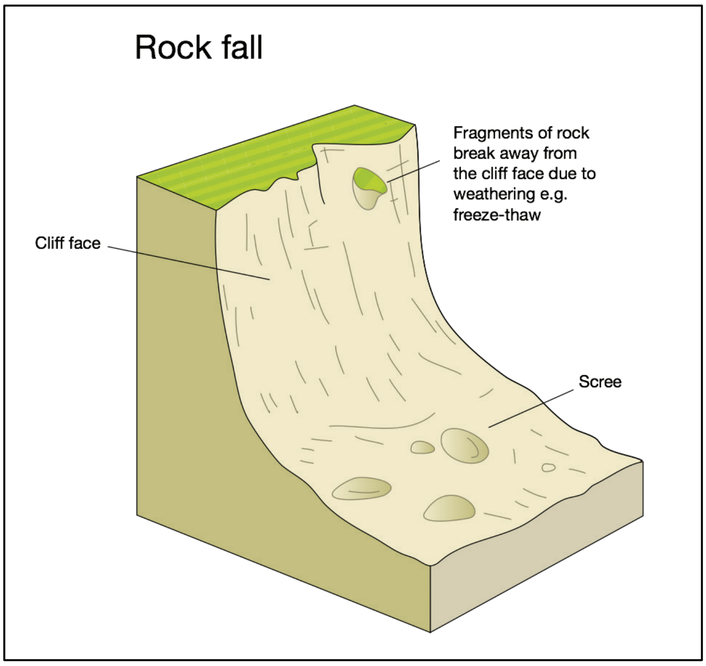


Figure 4. *An annotated diagram showing the main features of a rock fall.*

Mudslides

Mudslides occur when saturated soil and weak rock flows down a slope. These typically occur where cliffs are made up of boulder clay.

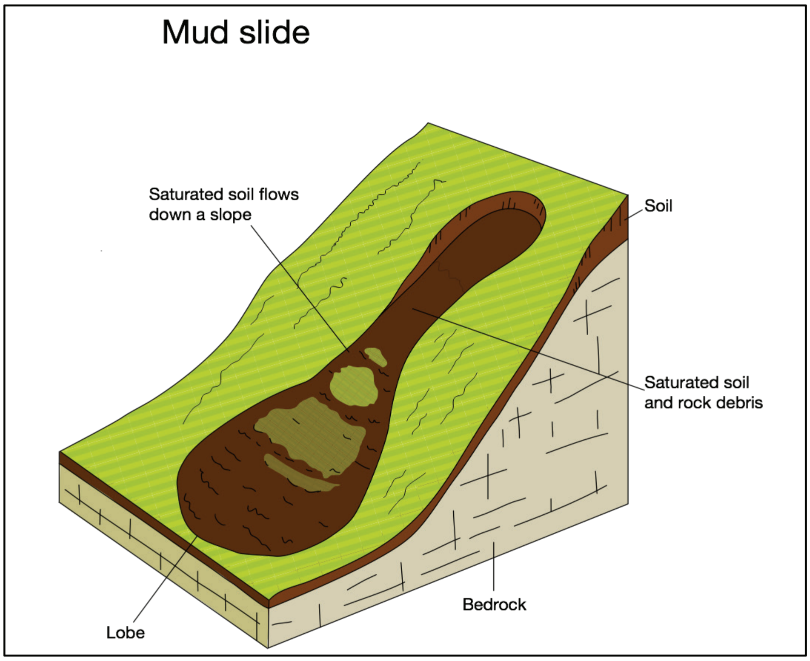


Figure 5. *An annotated diagram showing the main features of a mudslide.*

Types of Slope Mass Movement

A slope mass movement is defined as the movement of material down a slope. Thus landslides, rock-slides, mudslides and rock-falls are all types of slope mass movement. Not all forms of slop mass movement are obviously noticeable or quick. Here are some of the major varieties of slope mass movement briefly outlined:

Creep. A slow movement of rock and soil down a slope, usually around 1 mm to 10 m a year. The creep is usually the result of overburdening and increased pressure of the rocks and soil in the slope. Creeps usually occur on large slope with a gradual to moderate incline.

Slide. Slides are a more rapid movement of rock and soil down a slope. Usually occurring relatively quickly. Slides are the cause of multiple factors including erosion, lubrication of the soil and rocks in a slope and the giving way of the slope when under pressure. A slide is the movement of coherent blocks of soil and rock down a slope. Shallow slides are most common in the Adelaide area (Geoscience Australia, 2012). These occur when the smaller surface layer of rocks and soil is permeable to water and increases in weight during periods of high rainfall. Once the surface layer becomes heavy enough it will slide down the slope along the less water permeable bottom layer.

Flow. A flow is a torrent of water flowing down a slope with enough force to carry rocks and sediment down the slope. Larger stronger flows have enough force to carry boulders and large quantities of soil and sediment down a slope. Lesser flows may just carry soil and fine pebbles and gravel. Flows may also carve gullies and grooves into the slope as the water moves down the slope.
Fall. A fall is usually made up of moderate to large rocks and occurs often after the edge of a steep slope crumbles due to heavy rainfall or erosion. In a fall the rocks free fall or tumble down the slope. Rocks that fall can vary in size from rocks as large as cars to small rocks and pebbles .

These different kinds of mass movements are arranged from slowest (left) to fastest (right).

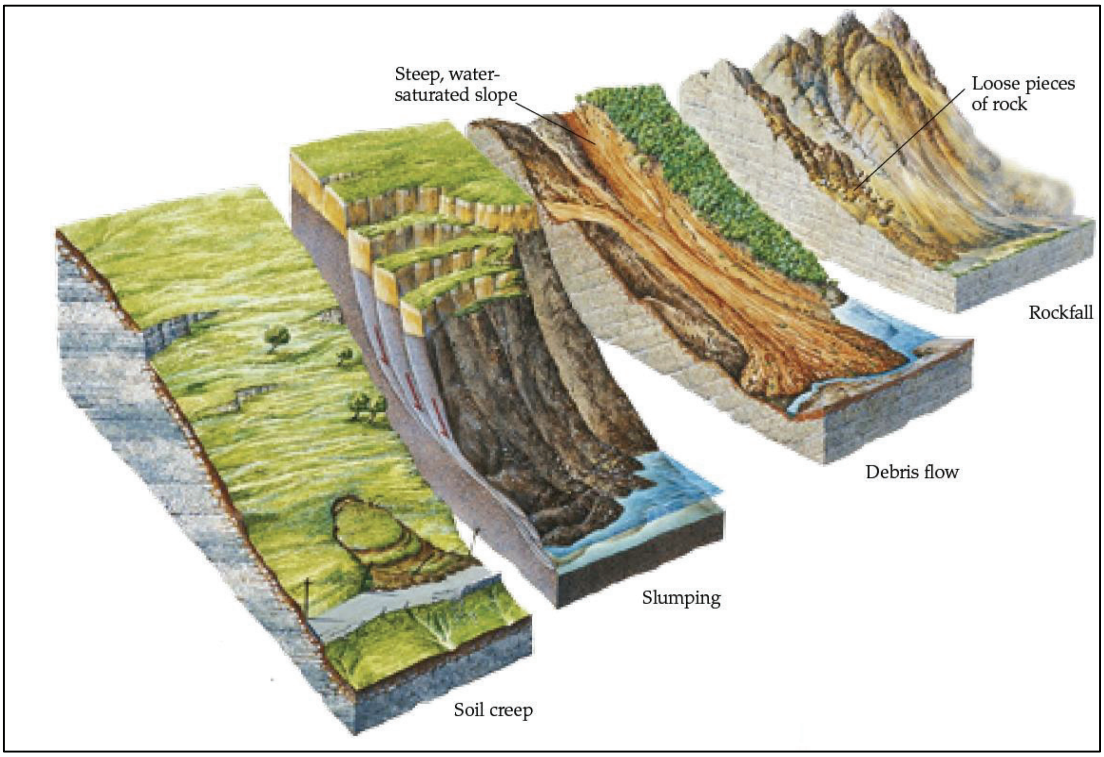


Figure 6. *A diagram showing the difference between different slope mass movements. The slope labelled slumping shows what above is called a slide. The slope labelled a debris flow show what is described above as flow.*
(Source: https://landandrockslidesadelaide.wordpress.com/types-of-slope-mass-movement/. Source: https://www.internetgeography.net/topics/what-is-mass-movement/)

2. Types of submarine mass movement

There are basically three types of submarine mass movement. The three types are based on disintegration.

(a) Submarine slumps – coherent blocks break and slip.
(b) Submarine debris flows – moving material breaks apart.
(c) Turbidity currents – sediment moves as a turbulent cloud.

Submarine slumps - semi-coherent blocks (olistostromes) slip downslope on weak mud detachments. Occasionally, the layers constituting the blocks become contorted as they move.

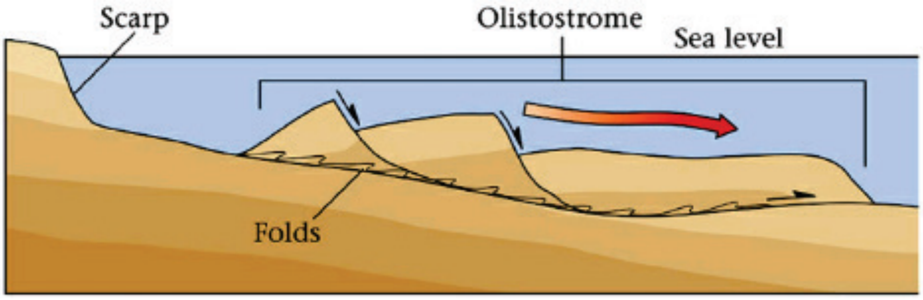


Figure 7. *Submarine slumps*

Submarine debris flows

Submarine Debris Flows - the moving mass breaks apart to form a slurry containing larger clasts (pebbles to boulders) in a mud matrix.

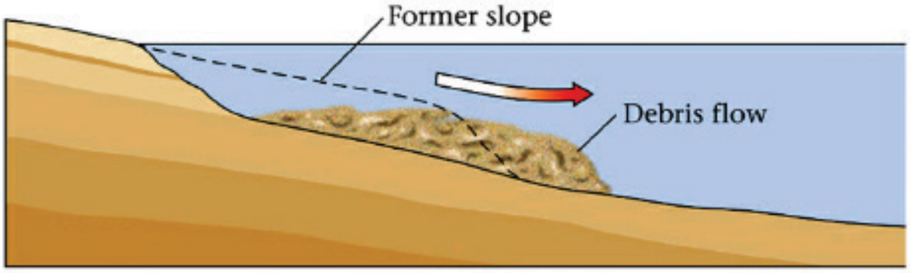


Figure 8. *Submarine debris flows*

3. Deposits from mass movement

Physical and chemical weathering of bedrock produce disaggregated particles that accumulate on the land surface in the absence of erosional processes adequate to remove them. In locations with sufficient topographic relief, gravitational forces acting on these disaggregated particles cause them to move down the slopes and accumulate as distinctive deposits along the lower portions of slopes, in topographic depressions, and especially at the bases of cliffs. The terms colluvium or colluvial materials are used to refer to deposits that have been transported by gravitational forces.

The characteristics of colluvial materials vary according to the characteristics of the bedrock sources and the climate under which weathering and transport occur. Generally, colluvium is weakly stratified and consists of a heterogeneous mixture of soil and rock fragments ranging in size from clay particles to rocks a meter or more in diameter. These deposits are often only marginally stable. Because they are found along the lower portions of valley sides, such deposits frequently need to be partially excavated to allow passage of transportation facilities.

A general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rain wash, sheet wash, or slow continuous downslope creep, usually collecting at the base of gentle slopes or hillsides.

Typically, colluvium is a poorly sorted mixture of angular rock fragments and fine-grained materials. These deposits rarely are more than 8 to 10 m thick, and they usually are thinnest near the crest and thickest near the toe of each slope.

Colluvium is the loose debris that accumulates at the bottom of a steep slope due to downward movement caused by erosion.

Figure 9. *Colluvium is sediment that has moved downhill to the bottom of the slope without the help of running water in streams. Gravity and sheet wash during rain storms are the predominant agents of colluvium deposition* (Source: https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/talus-pile-or-talus-slope)

Relatively rapid physical fragmentation of bedrock exposed on cliffs frequently produces large number of rock fragments ranging in size from small to deposit. After falling from the cliff, these fragments accumulate at the base to form a wedge shaped deposit. A number of terms are used to describe these deposits, talus and scree being the most common. The term talus is derived from the French word for a slope on the outside of a fortification; originally it referred to the landform rather than the material. More recently, talus has been used to describe the material itself and talus slope has been used to define the landform. Often the cliff is not perfectly straight but contains recesses or ravines that tend to funnel the rock fragments into a chute; these fragments form a conical pile called a talus cone. In many cases multiple chutes form overlapping cones, creating a complex intermixing of talus materials.

Geologists define talus as the pile of rocks that accumulates at the base of a cliff, chute, or slope. The formation of a talus slope results from the talus accumulation.

Because the term "talus" incorporates the concept of a pile, many geologists prefer it to "talus pile" and reserve the term "talus slope" for specific reference to the surface of the talus.

The recognition and characterization of talus slopes is often important in determining the potential for mass movements (landslides, etc.). Movements occur whenever the talus slope exceeds the critical angle. The exact angle at which failure takes place depends upon the materials (e.g., rock type), rock size, moisture content, but dry homogenous materials in a pile generally experience slope failure when the angle of repose (the resting slope angle) exceeds 33–37°. The critical angle lowers as materials become less intrinsically cohesive or when friction between particles is reduced by rain or other forms of moisture. Moisture also adds to the overall mass of the slope and thus increases the gravitational force on the slope.

For example, if a cliff or rock formation is composed of shale, the processes of weathering and the force of gravity (a shear stress) allow the downslope accumulation of shale rock fragments and debris at the base of the formation. The talus slope is triangular, with the internal angles of the sides of the triangle (the slope's angle of repose) limited by the critical angle.

Figure 10. *Talus in the Wind River Range* (Source: https://pmags.com/talus-vs-scree-what-is-the-difference)

4. Causes of mass movement

Mass movement can be triggered by natural events like earthquakes, volcanic eruptions and flooding, but gravity is its driving force.

Although gravity is the driving force of mass wasting, it is impacted mainly by the slope material's strength and cohesiveness as well as the amount of friction acting on the material. If friction, cohesion, and strength (collectively known as the resisting forces) are high in a given area, mass wasting is less likely to occur because the gravitational force does not exceed the resisting force.

The angle of repose also plays a role in whether a slope will fail or not. This is the maximum angle at which loose material becomes stable, usually 25°-40°, and is caused by a balance between gravity and the resisting force. If, for example, a slope is extremely steep and the gravitational force is greater than that of the resisting force, the angle of repose has not been met and the slope is likely to fail. The point at which mass movement does occur is called the shear-failure point.

There are a number of factors besides gravitational pull that initiates mass movement.

Volcanic activity

A volcanic eruption many times causes huge mudflows. The snow cover of a volcano melts in the heat and mixes with the soil to form mud as the magma in the volcano stirs preceding an eruption. This causes mass movement.

Earthquake shocks results in portions of mountains and hills to break loose and slide downwards. The vigorous shaking of an already-unstable slope by seismic waves may cause it to fail. Typically, the higher the magnitude of an earthquake, the more mass wasting will occur.

Landslides

When masses of rock, earth, or debris move down a slope there is landslide. The movement may be small or massive, slow or at a high speed, carrying along with it considerable amount of soil. These are sudden movements and with the effect of geological agents such as water, wind and can cause a movement of land.

A landslide is the most common form of mass wasting that includes a wide range of ground movements, such as rockfalls, which occurs when any rock or boulder falls without any obstruction down a cliff.

Submarine landslide occurring underwater, in coastal and onshore environments is caused when certain pre-existing factors create conditions that make the underwater area/slope prone to move from its primary position causing a landslide.

Mudslide

Also known as debris flows, mudslides especially after torrential rain or cloud burst, are moving body of rock, earth, and other debris saturated with water causing mass wasting or mass movement. When water rapidly accumulates in the ground, during rapid snow melt, it changes the surface of the area into a flowing river of mud. A mudflow is a flowing mixture of debris and water, usually moving down a channel.

Landslides should not be confused with mud flows, a form of mass wasting involving very to extremely rapid flow of debris that has become partially or fully liquefied by the addition of significant amounts of water to the source material.

Weathering and erosion

Human modification of the land or weathering and erosion help loosen large chunks of earth and start them sliding downhill.

Ice wedging

Ice wedging causes mass movement. During an earthquake, loose rock particles dislodge creating crevices. Ice wedging is the formation of ice crystals in the tiny crevices between rocks. When the water freezes, it expands, putting force on the rocks which break apart and fall from mountains slopes.

Other causes

Vibrations from machinery, traffic, weight loading from accumulation of snow; stockpiling of rock or ore; from waste piles and from buildings and other structures.

Another natural cause of mass wasting is excess water on a slope due to melting snow or heavy rains. This cause slope increases. If the sediment is loose, the excess water moves it down the slope, causing mass wasting.

Humans are also responsible for mass wasting. Deforestation is one of them. It exposes soil to erosion leaving it without protection against the force of raindrops, which moves loose rocks and soil.

However, the most important factor to initiate mass movement is the gravitational pull of the earth.

5. Mass movement controls

All slopes are susceptible to mass movement hazards if a triggering event occurs. Thus, all slopes should be assessed for potential mass movement hazards. Mass movement events can sometimes be avoided by employing engineering techniques to make the slope more stable. Among them are:

- Steep slopes can be covered or sprayed with concrete covered with a wire mesh to prevent rock falls.
- Retaining walls could be built to stabilize a slope.
- If the slope is made of highly fractured rock, rock bolts may be emplaced to hold the slope together and prevent failure.
- Drainage pipes could be inserted into the slope to more easily allow water to get out and avoid increases in fluid pressure, the possibility of liquefaction, or increased weight due to the addition of water.
- Over steepened slopes could be graded or terraced to reduce the slope to the natural angle of repose.
- In mountain valleys subject to mudflows, plans could be made to rapidly lower levels of water in human-made reservoirs to catch and trap the mudflows.
- Some slopes, however, cannot be stabilized. In these cases, humans should avoid these areas or use them for purposes that will not increase susceptibility of lives or property to mass movement hazards.

Figure 11. *Rock fall netting is hexagonal wire mesh to prevent rocks from falling onto roads.*

Figure 12. *Retaining wall to stabilise a slope.*

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (including pictures) and ask questions on mass movement. Teachers can take students out for an excursion to a nearby mass movement site to observe and provide possible, related explanations.	Students will use the information provided to answer questions on mass movement.
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Construct models of the different methods of retaining mass movement- STEAM	
Teaching Strategies Teachers will provide the criteria and the materials to construct models of the different methods of retaining mass movement.	**Learning Strategies** In groups, students read the criteria and follow the steps and use the materials available to create models of the different methods of retaining mass movement.

Recommended Resources:

- https://www.eartheclipse.com/geology/types-causes-mass-wasting-rocks.html
- https://www.internetgeography.net/topics/what-is-mass-movement/
- https://landandrockslidesadelaide.wordpress.com/types-of-slope-mass-movement/.
- https://www.tulane.edu/~sanelson/Natural_Disasters/slopestability.htm
- Internet

Unit 4: Surface Processes and Groundwater

Content Standard	**12.2.4** Students will be able to understand and explain the processes of weathering and erosion, and the groundwater system.
Benchmark	**12.2.4.5** Analyse the features of the ground water system.

Topic 5 : Groundwater

Learning Objectives:

By the end of this topic, the students will be able to;

- Identify and describe the different types of groundwater.
- Explain groundwater zones.
- Identify and describe the different types of aquifer.
- Explain the importance and uses of ground water.
- Explain how the following human activities affect the quality and quantity of groundwater such as urbanisation, waste disposal, agriculture, and conservation.

Essential questions

1. What are the different types of groundwater?
2. What are the groundwater zones?
3. What are the different types of aquifer?
4. Why is the groundwater important?
5. How can groundwater be polluted?
6. What are the effects of over-pumping groundwater?

Vocabulary: Groundwater, aquifer, unsaturated zone, saturated zone, unconfined aquifer, confined aquifer.

Concepts	Essential Skills	Essential Values and Attitudes
• Types of groundwater • Groundwater zones • Types of aquifer • Importance and uses of groundwater • Effects of excessive pumping of groundwater	• Making generalisations • Reasoning • Analysing • Comparing and contrasting	• Open-minded, desire to learn, optimistic, critical

Content Background

1. Types of groundwater

Groundwater is fresh water (from rain or melting ice and snow) that soaks into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. Groundwater accounts for nearly 95 percent of the nation's fresh water resources. It can stay underground for hundreds of thousands of years, or it can come to the surface and help fill rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring or be pumped from a well.

The types of groundwater are classified according to its origin.

Juvenile water

Juvenile water is "new" water that is in, or derived from, materials deep within the Earth and has not previously appeared at the Earth's surface or circulated in the atmosphere. For example, magmatic water, volcanic water and cosmic water.

Meteoric water

Meteoric water is the water derived from precipitation (snow and rain). This includes water from lakes, rivers, and ice melts, which all originate from precipitation indirectly. While the bulk of rainwater or meltwater from snow and ice reaches the sea through surface flow, a considerable portion of meteoric water gradually infiltrates into the ground. This infiltrating water continues its downward journey to the zone of saturation to become a part of the groundwater in aquifers.

Connate water

Water trapped in the pores of a rock during formation of the rock. The chemistry of connate water can change in composition throughout the history of the rock. Connate water can be dense and saline compared with seawater. Formation water, or interstitial water, in contrast, is simply water found in the pore spaces of a rock, and might not have been present when the rock was formed. Connate water is also described as *fossil water*.

Groundwater is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. It originates as rainfall or snow, and then moves through the soil into the groundwater system, where it eventually makes its way back to surface streams, lakes, or oceans.

2. Groundwater zones

Groundwater is found in two zones. The unsaturated zone (or vadoze), immediately below the land surface, contains water and air in the open spaces, or pores. The saturated zone (or phreatic), a zone in which all the pores and rock fractures are filled with water, underlies the unsaturated zone. The top of the saturated zone is called the water table. The water table may be just below or hundreds of feet below the land surface.

How does the ground store water?

Groundwater is stored in the tiny open spaces between rock and sand, soil, and gravel. How well loosely arranged rock (such as sand and gravel) holds water depends on the size of the rock particles. Layers of loosely arranged particles of uniform size (such as sand) tend to hold more water than layers of rock with materials of different sizes. This is because smaller rock materials settle in the spaces between larger rock materials, decreasing the amount of open space that can hold water. Porosity (how well rock material holds water) is also affected by the shape of rock particles. Round particles will pack more tightly than particles with sharp edges. Material with angular-shaped edges has more open space and can hold more water.

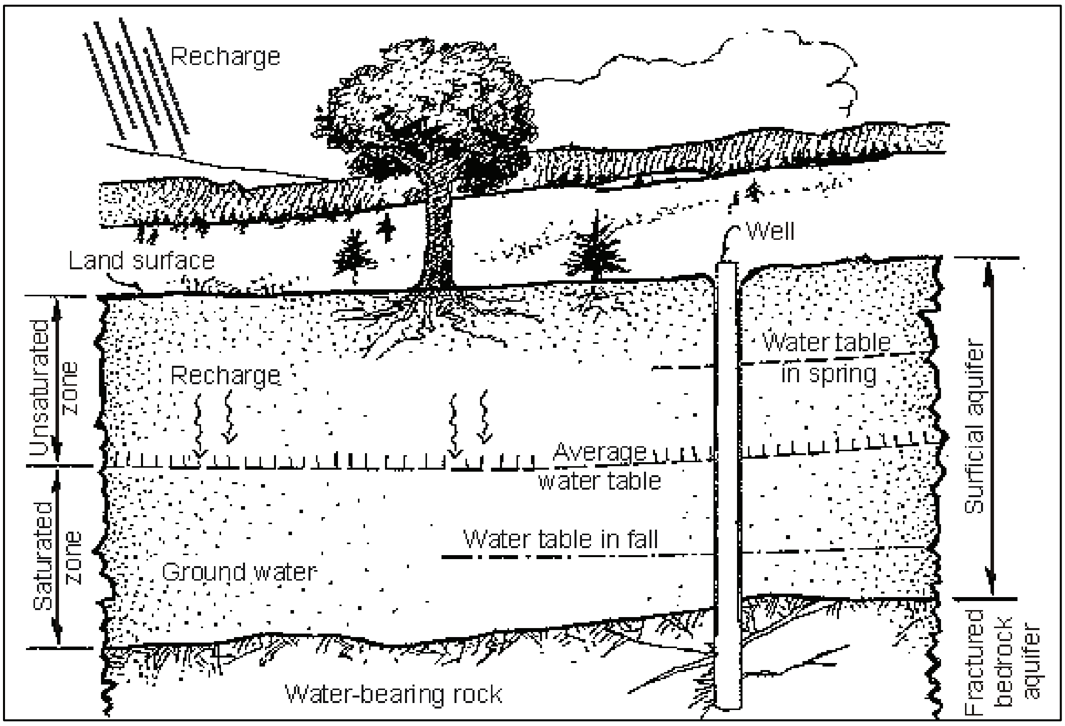


Figure 1. *Groundwater zones*

Zone of aeration (unsaturated or vadoze)
Pores in rock and soil are filled with air and some water.

Capillary fringe
Area just above the water table where the water is pulled up

Water table
The boundary line between the zone of aeration and the zone of saturation

Zone of saturation (saturated or phreatic)
Water fills up all of the empty spaces

3. Types of aquifer

As part of the water cycle, some precipitation infiltrates the ground and percolates down until it reaches a depth where all the fractures, crevices and pore spaces are saturated with water. In this saturated zone – called an *aquifer* – the water is called *groundwater*. The upper surface of a zone of saturation is the water table. In other words, the water table is the first occurrence of groundwater. Above the water table is the zone of aeration . There is some water in the zone of aeration, but it will not flow into a well. So successful wells need to be deeper than the water table.

Aquifers are geologic formations – layers of sand, gravel and rock – where significant amounts of water can be stored, transported or supplied to a well or a spring. They are irregular in shape, and can be close to the surface, or very deep.

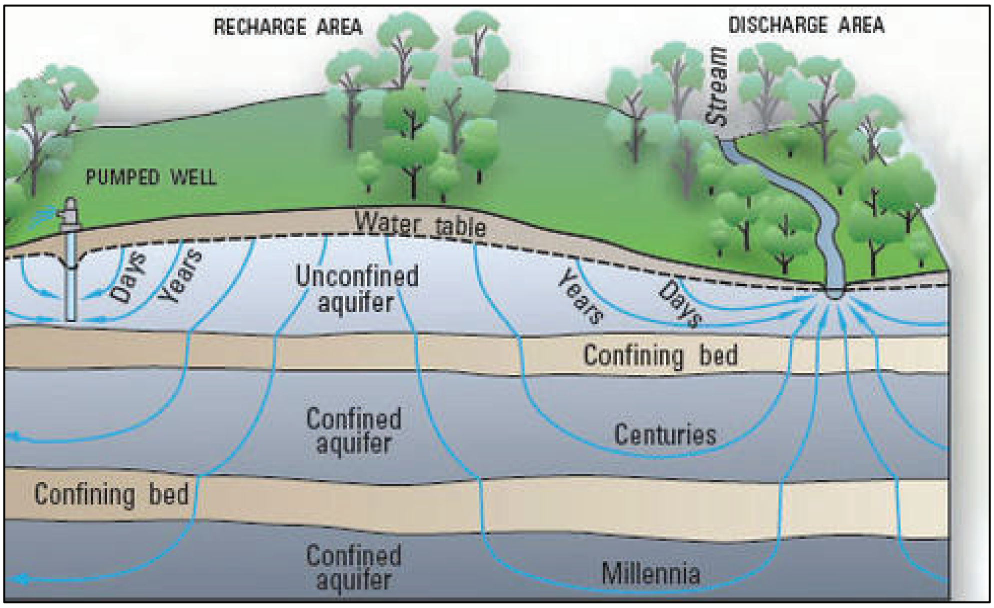


Figure 2. *Conceptual groundwater-flow diagram*
(*Source:* https://www.usgs.gov/media/images/conceptual-groundwater-flow-diagram)

An aquifer is a water-bearing layer in the underground. There are several kinds of aquifers. The most commonly used types are the confined (or artesian) aquifer, the unconfined (or free, phreatic) aquifer and the semi-confined aquifer. There are also complex aquifer systems consisting of a number of different aquifer types.

Confined (artesian) aquifer

A confined (artesian) aquifer is an aquifer bounded both at the bottom and at the top by an impermeable stratum (aquiclude) and fully filled with water which is usually under (artesian) pressure. When perforating a hole into the ground until reaching the confined aquifer, one will see the water level in the hole rise to above the top of the aquifer and perhaps even above the land surface. In the latter case the water will flow out from the hole over the land surface. In the upstream part the confined aquifer gradually changes into an unconfined aquifer (see below) which forms the recharge zone where rain water reaches the water-table.

Unconfined aquifer

An unconfined (free, phreatic) aquifer is an aquifer underlain by an impermeable stratum, but the top of the aquifer consists of soil layers that are permeable enough to provide easy passage of water, at least in vertical sense. Such an aquifer has a free water table or phreatic surface.
When perforating a hole into the ground until it fills with water, and letting the water come to rest, the water level in the hole can be observed and it indicates the level of the water table in the aquifer outside the hole. Many alluvial fans and river plains have unconfined aquifers in the upper part of the sediment deposits.

The simple aquifer shown in Figure 2 is termed an unconfined aquifer because the aquifer formation extends essentially to the land surface. As a result, the aquifer is in pressure communication with the atmosphere. Unconfined aquifers are also known as water table aquifers because the water table marks the top of the groundwater system.

A second common type of aquifer is a confined aquifer, which is isolated from pressure communication with overlying or underlying geologic formations – and with the land surface and atmosphere – by one or more confining layers or confining units. Confined aquifers differ from unconfined aquifers in two fundamental and important ways. First, confined aquifers are typically under considerable pressure, which may be derived from recharge at a higher elevation or from the weight of the overlying rock and soil (known as the overburden). In some cases, the pressure is high enough that wells drilled into the aquifer are free-flowing. This condition requires that the water pressure in the aquifer is sufficient to drive water up the wellbore and above the land surface, and such wells are called artesian wells (Fig. 3). Second, confined aquifers typically remain saturated over their entire thickness, even as water is removed by pumping wells. Water extracted from the aquifer comes only from the depressurization of the aquifer – a combination of depressurization and expansion of the water itself, and relaxation of the aquifer formation upon reduction in pressure (Fig. 4).

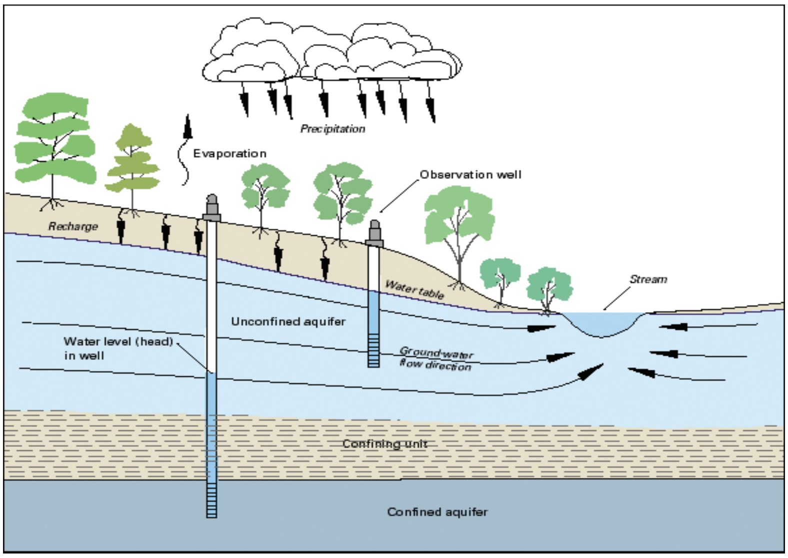


Figure 3. *Schematic cross-sectional diagram showing a layered system with an upper unconfined aquifer above a confining unit, and underlain by a confined aquifer. Note the water level in the two wells: In the unconfined aquifer, the water level in the well is the same as the height of the water table. In the confined aquifer, the water level is higher than the top of the aquifer – indicating that the aquifer is fully saturated and that the water is under pressure* (Source: USGS Water Science Photo Gallery)

The third main type of aquifer is a perched aquifer (Fig. 4). Perched aquifers occur above discontinuous aquitards, which allow groundwater to “mound” above them. These aquifers are perched, in that they sit above the regional water table, and within the regional vadose zone (i.e. there is an unsaturated zone below the perched aquifer). The dimensions of perched aquifers are typically small (dictated by climate conditions and the size of aquitard layers), and the volume of water they contain is sensitive to climate conditions and therefore highly variable in time.

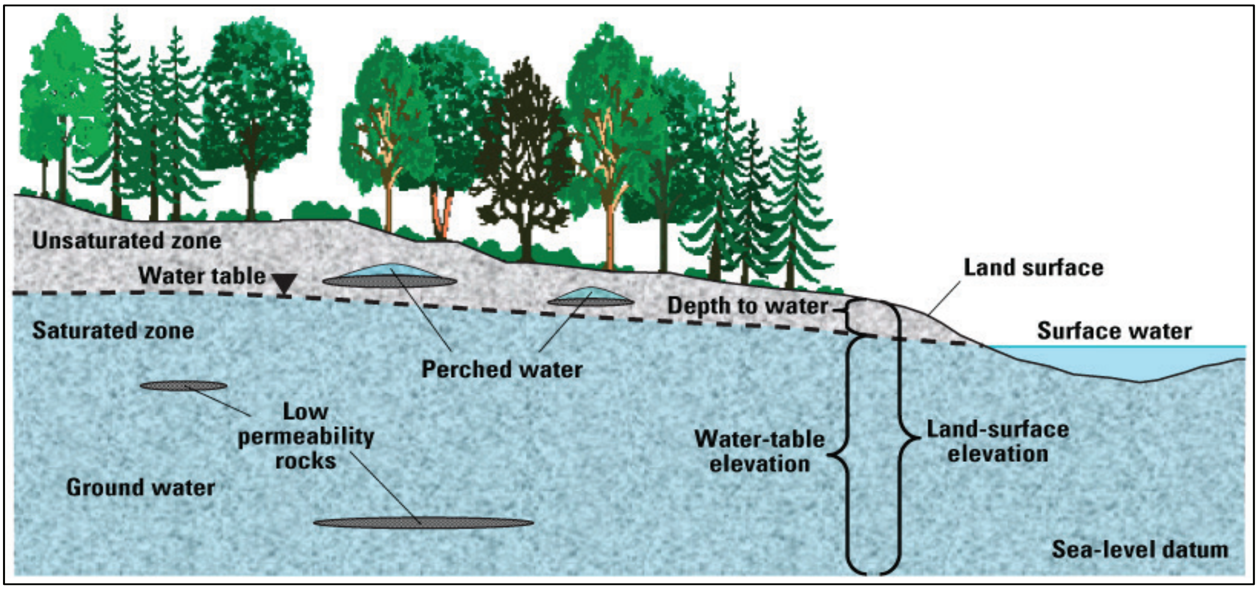


Figure 4. *Schematic cross-section showing the occurrence of perched aquifers above an unconfined aquifer* (Source: https://pubs.usgs.gov/sir/2008/5059/figure2.html)

4. Importance and uses of groundwater

Groundwater is also very important as it supplies springs, and much of the water in our ponds, marshland, swamps, streams, rivers and bays. Although it is “out of sight,” it is critical that we learn about groundwater, how it is part of the water cycle, and the importance of protecting and maintaining the quality and quantity of this water resource.

Uses of groundwater

Roughly 60 percent of global groundwater use is for irrigation; most of the rest is used in households and industry. Groundwater uses vary significantly by country, and partly depend on climate. In some countries with abundant rainfall, such as Indonesia and Thailand, irrigation needs are very low, so household water supply is the main use for groundwater. Globally, over 2 billion people use groundwater as a source of drinking water. In some more arid countries such as Pakistan, Saudi Arabia, and Syria, irrigation accounts for 90 percent of groundwater use.

5. Effects of excessive pumping and depletion of groundwater

Groundwater is the largest source of usable, fresh water in the world. In many parts of the world, especially where surface water supplies are not available, domestic, agricultural, and industrial water needs can only be met by using the water beneath the ground.

Groundwater depletion is primarily caused by sustained groundwater pumping. Some of the negative effects of groundwater depletion:

Lowering of the water table

Excessive pumping can lower the groundwater table, and cause wells to no longer be able to reach groundwater.

Increased costs

As the water table lowers, the water must be pumped farther to reach the surface, using more energy. In extreme cases, using such a well can be cost prohibitive.

Reduced surface water supplies

Groundwater and surface water are connected. When groundwater is overused, the lakes, streams, and rivers connected to groundwater can also have their supply diminished.

Land subsidence

Land subsidence occurs when there is a loss of support below ground. This is most often caused by human activities, mainly from the overuse of groundwater, when the soil collapses, compacts, and drops.

Water quality concerns

Excessive pumping in coastal areas can cause saltwater to move inland and upward, resulting in saltwater contamination of the water supply.

Teaching and Learning Strategies

Teaching Strategies:	Learning Strategies
Teachers prepare information (including pictures) and ask questions on groundwater. Teachers can show videos related to groundwater.	Students will use the information provided to answer questions on groundwater.
STEAM Approach Learning Objective: By the end of the topic, students will be able to; • Construct models of the different methods of preventing mass movement- STEAM	
Teaching Strategies Teachers will provide the criteria and the materials to construct models of the groundwater system.	**Learning Strategies** In groups, students read the criteria and follow the steps and use the materials available to create models of the groundwater system.
Recommended Resources: • https://www.groundwater.org/get-informed/groundwater/overuse.html • https://www.usgs.gov/media/images/conceptual-groundwater-flow-diagram • Internet	

Standards-Based Lesson Planning

What are Standards-Based Lessons?

In a Standards-Based Lesson, the most important or key distinction is that, a student is expected to meet a defined standard for proficiency. When planning a lesson, the teacher ensures that the content and the methods of teaching the content enable students to learn both the skills and the concepts defined in the standard for that grade level and to demonstrate evidence of their learning.

Planning lessons that are built on standards and creating aligned assessments that measure student progress towards standards is the first step teacher must take to help their students reach success. A lesson plan is a step-by-step guide that provides a structure for an essential learning.

When panning a standards-based lesson, teacher instructions are very crucial for your lessons. How teachers instruct the students is what really points out an innovative teacher to an ordinary teacher. Teacher must engage and prepare motivating instructional activities that will provide the students with opportunities to demonstrate the benchmarks. For instance, teacher should at least identify 3-5 teaching strategies in a lesson; teacher lectures, ask questions, put students into groups for discussion and role play what was discussed.

Why is Standards-Based Lesson Planning Important?

There are many important benefits of having a clear and organized set of lesson plans. Good planning allows for more effective teaching and learning. The lesson plan is a guide and map for organizing the materials and the teacher for the purpose of helping the students achieve the standards. Lesson plans also provide a record that allows good, reflective teachers to go back, analyze their own teaching (what went well, what didn't), and then improve on it in the future.

Standards-based lesson planning is vital because the content standards and benchmarks must be comparable, rigorous, measurable and of course evidence based and be applicable in real life that we expect students to achieve. Therefore, teachers must plan effective lessons to teach students to meet these standards. As schools implement new standards, there will be much more evidence that teachers will use to support student learning to help them reach the highest levels of cognitive complexity. That is, students will be developing high-level cognitive skills.

Components of a Standards-Based Lesson Plan

An effective lesson plan has three basic components;

- aims and objectives of the course;
- teaching and learning activities;
- assessments to check student understanding of the topic.

Effective teaching demonstrates deep subject knowledge, including key concepts, current and relevant research, methodologies, tools and techniques, and meaningful applications.

Planning for under-achievers NORMA

Who are underachieving students?
Under achievers are students who fail or do not perform as expected.
Underachievement may be caused by emotions (low self-esteem) and the environment (cultural influences, unsupportive family)

How can we help underachievement?
Underachievement varies between students. Not all students are in the same category of underachievement.
Given below a suggested strategies teachers may adopt to assist underachievers in the classroom.

- Examine the Problem Individually

It is important that underachieving students are addressed individually by focusing on the student's strengths.

- Create a Teacher-Parent Collaboration

Teachers and parents need to work together and pool their information and experience regarding the child. Teachers and parents begin by asking questions such as;

- In what areas has the child shown exceptional ability?
- What are the child's preferred learning styles?
- What insights do parents and teachers have about the child's strengths and problem areas?
- Help student to plan every activity in the classroom
- Help students set realistic expectations
- Encourage and promote the student's interests and passions.
- Help children set short and long-term academic goals
- Talk with them about possible goals.
- Ensure that all students are challenged (but not frustrated) by classroom activities
- Always reinforce students

Standards-Based Lesson Planning

Sample Standards-Based Lesson Plan (Integrating STEAM)

TOPIC: Mining and the environment

Lesson Topic: Mine Closure Plan
Grade: 12
Length of Lesson: 40 minutes

National Content Standard 12.1.1: Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.

Grade Level Benchmark 12.2.1.5 Explore and analyse the environmental regulations of mining activities set by the government.

Essential Knowledge, Skills, Values, and Attitudes

Knowledge: Mine closure planning
Skills: Evaluating - Reasoning
Values: Common good, sustainability, and interdependence
Attitudes: Caring, responsible, and respect

STEAM Knowledge and Skill

Knowledge: Environmental rehabilitation after mine closure
Skill: Evaluating - reasoning
Performance Indicator: Identify environmental rehabilitation after mine closure

STEAM Performance Indicator: As above

Materials: Copies of mine closure plan

- **Lesson Objective:** Students will be able to differentiate between Standard units and Derived Units

Essential Questions:

What are standard and derived SI units?’
What STEAM principles and practices can be used to enhance the ability to make conversions and derivations between units?

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
• Explain what students will learn and how it will be useful. • Connect what they will learn to prior learning or experience.	• Listen to the teacher.
Body	
Modelling	
• Identify and discuss a Standard and Derived units.	• Listen and respond when prompted by the teacher.
Guided Practice	
• Give students a copy of the conversion scale. • Ask students to read the conversion scale and identify one process involved in deriving units from standard units. • Ask students to stop and give a process for deriving units. • Ascertain if students understand what they are supposed to do.	• Read the conversion scale and identify one process involved in deriving units from standard units. • Give one process given in the conversion scale in deriving units from standard units. • Let teacher know if they understand what to do.
Independent Practice	
• Ask students to read the conversion scale and identify one process involved in deriving units from standard units. • Ask students to suggest and defend one process to derive units from standard units.	• Read the conversion scale and identify one process involved in deriving units from standard units. • Suggest and defend one other conversion process to derive units from standard units.
Conclusion	
• Emphasise the reasons given in the conversion scale to derive units from standard units. • Ask students to provide a process given in the process for deriving units.	• Listen to the teacher. • Give reasons to make conversions and their importance, orally

Performance Assessment and Standards

<table>
<tr><td colspan="5">National Content Standard : Students will be able to trace the origins of Earth resources including mineral deposits, coal, petroleum, and natural gas and their economic development</td></tr>
<tr><th>Lesson Topic</th><th>Topic</th><th>Benchmark</th><th colspan="2">Performance Assessment</th></tr>
<tr><td rowspan="4">Mine Closure Plan</td><td>Mining and the environment</td><td>12.2.1.5. Explore and analyse the environmental regulations of mining activities set by the government.</td><td colspan="2">Student reads one mine closure plan and identify its reasons for rehabilitating the natural environment</td></tr>
<tr><th colspan="4">PROFICIENCY RUBRIC</th></tr>
<tr><th>Advanced</th><th>Proficient</th><th>Partially Proficient</th><th>Novice</th></tr>
<tr><td>Identify all the reasons given in the mine closure plan for rehabilitating the environment, and justified at least one reason</td><td>Identify all the reasons given in the mine closure plan for rehabilitating the environment</td><td>Identify more than 50% of the reasons given in the mine closure plan for rehabilitating the environment</td><td>Identify less than 50% of the reasons given in the mine closure plan for rehabilitating the environment</td></tr>
</table>

STEAM Activity

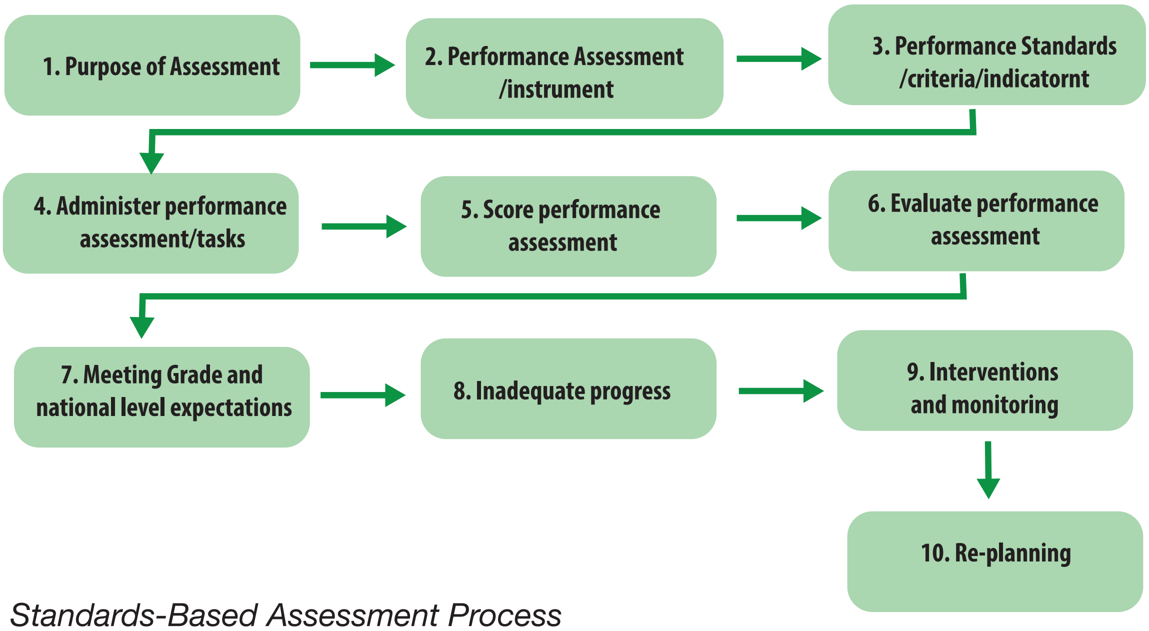
Students create a model of a mine that is going to be closed soon shown in the plan and the natural environment that is worth rehabilitating using the values of common good, sustainability, and interdependence; and the attitudes of caring, responsible, and respect.

Assessment, Monitoring and Reporting

What is Standards-Based Assessment (SBA)?

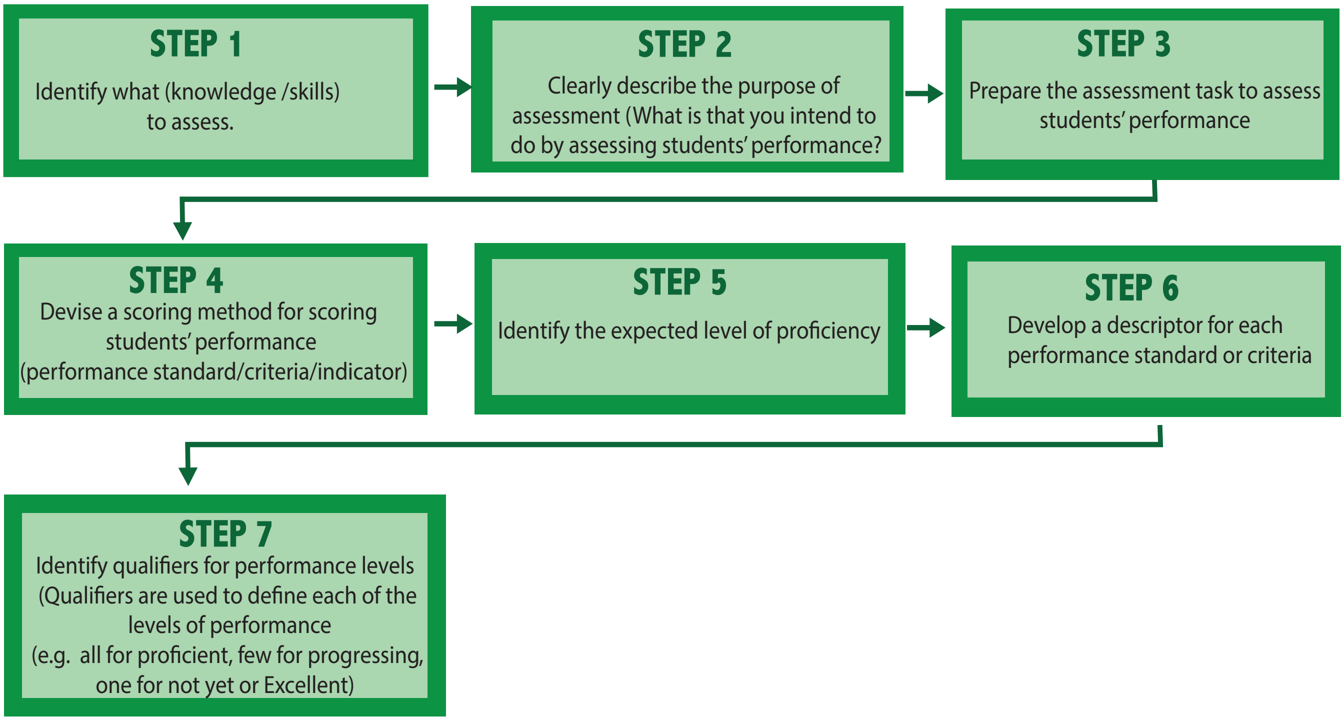
Assessment and reporting is an integral part of the delivery of any curriculum used in the schools. In Standard Based Curriculum (SBC) assessment encourages the use of benchmarks and commended types of assessment that promote standards for a range of purposes.

Standards-Based Assessment Cycle



Standards-Based Assessment Process

Teachers are required to use the steps outlined below when planning assessment. These steps will guide you to develop effective assessments to improve student's learning as well as evaluating their progress towards meeting national and grade –level expectations.



STEP 1
Identify what (knowledge /skills) to assess.

STEP 2
Clearly describe the purpose of assessment (What is that you intend to do by assessing students' performance?

STEP 3
Prepare the assessment task to assess students' performance

STEP 4
Devise a scoring method for scoring students' performance (performance standard/criteria/indicator)

STEP 5
Identify the expected level of proficiency

STEP 6
Develop a descriptor for each performance standard or criteria

STEP 7
Identify qualifiers for performance levels (Qualifiers are used to define each of the levels of performance (e.g. all for proficient, few for progressing, one for not yet or Excellent)

Purpose of Standards-Based Assessment

Standards-Based Assessment (SBA) serves different purposes. These include instruction and learning purposes. The primary purpose of SBA is to improve student learning so that all students can attain the expected level of proficiency or quality of learning.

Enabling purposes of SBA is to:

- Measure students' proficiency on well-defined content standards, benchmarks and learning objectives
- Ascertain students' attainment or progress towards the attainment of specific component of a content standard
- Ascertain what each student knows and can do and what each student needs to learn to reach the expected level of proficiency
- Enable teachers to make informed decisions and plans about how and what they would do to assist weak students to make adequate progress towards meeting the expected level of proficiency
- Enable students to know what they can do and help them to develop and implement strategies to improve their learning and proficiency level
- Communicate to parents, guardians, and relevant stakeholders the performance and progress towards the attainment of content standards or its components
- Compare students' performances and the performances of other students

Principles of Standards-Based Assessment

The principle of SBA is for assessment to be;

- emphasise on tasks that should encourage deeper learning,
- be an integral component of a course, unit or topic and not something to add on afterward,
- a good assessment requires clarity of purpose, goals, standards and criteria of practices that should use a range of measures allowing students to demonstrate what they know and can do,
- based on an understanding of how students learn of practices that promote deeper understanding of learning processes by developing their capacity for self-assessment,
- for improving performance that involves feedback and reflection,
- on-going rather than episodic,
- given the required attention to outcomes and processes, and

be closely aligned and linked to learning objectives, benchmarks and content standards

Standards-Based Assessment Types

In standards-Based Assessment, there are three broad assessments types.

1. Formative Assessment

Formative assessment includes ‘assessment *for* and *as Learning’* and is conducted during the teaching and learning of activities of a topic.

Purposes of assessment for Learning

- On-going assessment that allows teachers to monitor students on a day-to-day basis.
- Provide continuous feedback and evidence to the teachers that should enable them to identify gaps and issues with their teaching, and improve their classroom teaching practice.
- Helps students to continuously evaluate, reflect on, and improve their learning.

Purposes of assessment as Learning

- Occurs when students reflect on and monitor their progress to inform their future learning goals.
- Helps students to continuously evaluate, reflect, and improve their own learning.
- Helps students to understand the purpose of their learning and clarify learning goals.

2. Summative Assessment

Summative assessment focuses on ‘assessment *of learning’* and is cconducted after or at the conclusion of teaching and learning of activities or a topic.

Purposes of assessment of Learning

- Help teachers to determine what each student has achieved and how much progress he/she has made towards meeting national and grade-level expectations.
- Help teachers to determine what each student has achieved at the end of a learning sequence or a unit.
- Enable teachers to ascertain each student’s development against the unit or topic objectives and to set future directions for learning.
- Help students to evaluate, reflect on, and prepare for next stage of learning.

3. Authentic Assessment

- Is performed in a real life context that approximates as much as possible, the use of a skill or concept in the real world.
- Is based on the development of a meaningful product, performance or process
- Students develop and demonstrate the application of their knowledge, skills, values and attitudes in real life situations which promote and support the development of deeper levels of understanding.
- Uses either summative or formative assessment methods in real life context.

Authentic assessment refers to assessment that:

- Looks at students actively engaged in completing a task that represents the achievement of a learning objective or standard.
- Takes place in real life situations.
- Asks students to apply their knowledge, skills, values and attitudes in real life situations.
- Students are given the criteria against which they are being assessed.

Performance Assessment

Performance assessment is a form of testing that requires students to perform a task rather than select an answer from a ready-made list. For example, a student may be asked to explain historical events, generate scientific hypotheses, solve math problems, converse in a foreign language, or conduct research on an assigned topic. Teachers, then judge the quality of the student's work based on an agreed-upon set of criteria. It is an assessment which requires students to demonstrate that they have mastered specific skills and competencies by performing or producing something.

Types of performance assessment

i. Products

This refers to concrete tangible items that students create through either the visual, written or auditory media such as:

- Creating a health/physical activity poster.
- Video a class game or performance and write a broadcast commentary.
- Write a speech to be given at a school council meeting advocating for increased time for health and physical education in the curriculum.
- Write the skill cues for a series of skill photo's.
- Create a brochure to be handed out to parents during education week.
- Develop an interview for a favourite sportsperson.
- Write a review of a dance performance.
- Essays.
- Projects.

ii. Process Focused Tasks

It shows the thinking processes and learning strategies students use as they work such as:

- Survival scenarios.
- Problem solving initiative/adventure/ activities.
- Decision making such as scenario's related to health issues.
- Event tasks such as creating a game, choreographing a dance/gymnastics routine, creating an obstacle course.
- Game play analysis.
- Peer assessment of skills or performances.
- Self-assessment activities.
- Goal setting, deciding a strategy and monitoring progress towards achievement.

iii. Portfolio

This refers to a collection of student work and additional information gathered over a period of time that demonstrates learning progress.

iv. Performances

It deals with observable affective or psycho-motor behaviours put into action such as:

- Skills check during game play.
- Role plays.
- Officiating a game.
- Debates.
- Performing dance/gymnastics routines.
- Teaching a skill/game/dance to peers.

Assessment Strategies

It is important for teachers to know that, assessment is administered in different ways. Assessment does not mean a test only. There are many different ways to find out about student's strengths and weaknesses. Relying on only one method of assessing will not reflect student's achievement.

Provided in the table below is a list of suggested strategies you can use to assess student's performances. These strategies are applicable in all the standards-based assessment types.

Assessment Strategies

STRATEGY	DESCRIPTION
ANALOGIES	Students create an analogy between something they are familiar with and the new information they have learned. When asking students to explain the analogy, it will show the depth of their understanding of a topic.
CLASSROOM PRESENTATIONS	A classroom presentation is an assessment strategy that requires students to verbalize their knowledge, select and present samples of finished work, and organize their thoughts about a topic in order to present a summary of their learning. It may provide the basis for assessment upon completion of a student's project or essay.
CONFERENCES	A conference is a formal or informal meeting between the teacher and a student for the purpose of exchanging information or sharing ideas. A conference might be held to explore the student's thinking and suggest next steps; assess the student's level of understanding of a particular concept or procedure; and review, clarify, and extend what the student has already completed
DISCUSSIONS	Having a class discussion on a unit of study provides teachers with valuable information about what the students know about the subject. Focus the discussions on higher level thinking skills and allow students to reflect their learning before the discussion commences.
ESSAYS	An essay is a writing sample in which a student constructs a response to a question, topic, or brief statement, and supplies supporting details or arguments. The essay allows the teacher to assess the student's understanding and/or ability to analyse and synthesize information.
EXHIBITIONS/ DEMONSTRATIONS	An exhibition/demonstration is a performance in a public setting, during which a student explains and applies a process, procedure, etc., in concrete ways to show individual achievement of specific skills and knowledge.
INTERVIEWS	An interview is a face-to-face conversation in which teacher and student use inquiry to share their knowledge and understanding of a topic or problem, and can be used by the teacher to explore the student's thinking; assess the student's level of understanding of a concept or procedure and gather information, obtain clarification, determine positions, and probe for motivations.
LEARNING LOGS	A learning log is an ongoing, visible record kept by a student and recording what he or she is doing or thinking while working on a particular task or assignment. It can be used to assess student progress and growth over time.
OBSERVATION	Observation is a process of systematically viewing and recording students while they work, for the purpose of making programming and instruction decisions. Observation can take place at any time and in any setting. It provides information on students' strengths and weaknesses, learning styles, interests, and attitudes.
PEER ASSESSMENT	Assessment by peers is a powerful way to gather information about students and their understanding. Students can use set criteria to assess the work of their classmates.
PERFORMANCE TASKS	During a performance task, students create, produce, perform, or present works on "real world" issues. The performance task may be used to assess a skill or proficiency, and provides useful information on the process as well as the product.

PORTFOLIOS	A portfolio is a collection of samples of a student's work, and is focused, selective, reflective, and collaborative. It offers a visual demonstration of a student's achievement, capabilities, strengths, weaknesses, knowledge, and specific skills, over time and in a variety of contexts.
QUESTIONS AND ANSWERS (ORAL)	In the question–and-answer strategy, the teacher poses a question and the student answers verbally, rather than in writing. This strategy helps the teacher to determine whether students understand what is being, or has been, presented, and helps students to extend their thinking, generate ideas, or solve problems.
QUIZZES, TESTS, EXAMINATIONS	A quiz, test, or examination requires students to respond to prompts in order to demonstrate their knowledge (orally or in writing) or their skills (e.g., through performance). Quizzes are usually short; examinations are usually longer. Quizzes, tests, or examinations can be adapted for exceptional students and for re-teaching and retesting.
QUESTIONNAIRES	Questionnaires can be used for a variety of purposes. When used as a formative assessment strategy, they provide teachers with information on student learning that they can use to plan further instruction.
RESPONSE JOURNALS	A response journal is a student's personal record containing written, reflective responses to material he or she is reading, viewing, listening to, or discussing. The response journal can be used as an assessment tool in all subject areas.
SELECTED RESPONSES	Strictly speaking a part of quizzes, tests, and examinations, selected responses require students to identify the one correct answer. The strategy can take the form of multiple-choice or true/false formats. Selected response is a commonly used formal procedure for gathering objective evidence about student learning, specifically in memory, recall, and comprehension.
STUDENT SELF-ASSESSMENTS	Self-assessment is a process by which the student gathers information about, and reflects on, his or her own learning. It is the student's own assessment of personal progress in terms of knowledge, skills, processes, or attitudes. Self-assessment leads students to a greater awareness and understanding of themselves as learners.

Samples of Assessment Types

Sample 1: Formative Assessment

Strand 2: Earth Science
Unit 1: Earth Resources

Content Standard: 12.2.1 Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.

Benchmark: 12.2.1.1 Examine the common minerals, their formations and the uses of economic minerals.

Topic1 : Minerals

Lesson Title: Economic and Industrial Minerals

Lesson Objective: By the end of the lesson, students should be able to:

- Explain the difference between economic and industrial minerals.

Knowledge	Skills	Values and Attitudes
• Economic minerals • Industrial Minerals	• Explain the difference between economic minerals and industrial minerals (analyse)	• Display desire to learn the difference between economic and industrial minerals • Appreciate the usefulness of economic and industrial minerals

What to be assessed?

Explain the difference between economic minerals and industrial minerals.

Purpose of the assessment

To measure the students' proficiency on the achievement of the benchmark and learning objectives

Expected level of proficiency
Identify and explain the difference between economic minerals and industrial minerals

Performance Task

Explain clearly the difference between economic minerals and industrial materials with examples

Assessment Strategy

This assessment can be conducted in one lesson as an assessed lesson exercise

Assessment Tool

An exercise will be used to measure their level of proficiency

Assessment Scoring

Rubrics must be developed to articulate the real proficiency of the child. This is an analytical rubrics used to assess the child's learning through the assessment tool a lesson exercise.

Performance standards/ Criteria	**A**	**B**	**C**	**D**	**Score**
	Advance 10	**Proficient 9 - 5**	**Progressing 3 - 4**	**Not Yet 2**	**__/10 Marks**
Explain clearly the difference between economic minerals and industrial minerals with examples *(10 marks)*	Clear and correct explanation of the difference between economic minerals and industrial minerals with all examples provided	Correct explanation of the difference between economic minerals and industrial minerals with some examples provided	Satisfactory explanation of the difference between economic minerals and industrial minerals with few examples provided	Poor explanation of the difference between economic minerals and industrial minerals with one example provided	

Recommended Resources:

- Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p
- Internet
- PNG OresomeResources.com – Minerals and Energy Education

Sample 2 : Summative Assessment

Strand 2: Earth Science

Unit 1: Earth Resources

Content Standard 12.2.1: Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.

Benchmark: (12.2.1.1 – 12.2.1.5 (refer to the benchmarks unit 1 of strand 2)

Topic 1: Minerals
Topic 2: Fossil Fuels
Topic 3: Exploration and Mining of Minerals
Topic 4: Exploration and Extraction of Oil and Gas
Topic 5: Mining and the Environment

Lesson Topics: (Refer to the lesson topics in Unit 1 of Strand 2)

Skill(s): Understanding (identify, interpret), remembering (define), analyzing (investigate, compare, use, examine, analysis)

Instructional Objective (s): *(Refer to Topics in Unit 1 of Strand 2)*

Knowledge	Skills	Values and Attitudes
• Minerals • Fossil Fuels • Exploration and Mining of Minerals • Exploration and Extraction of Oil and Gas • Mining and the Environment	• Understanding (identify, interpret) • remembering (define) • analyzing (investigate, compare, use, examine, analysis)	• Appreciate the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in.

What is to be assessed?

The Unit, Unit 1: ‘Earth Resources’.

Purpose of the assessment

To measure students’ proficiency on the achievement of the benchmarks and learning objectives in this unit. (This assessment is to be conducted after teaching the unit)

Expected level of proficiency

All students are expected to;

- Describe the difference between economic and industrial minerals.
- Describe what fossil fuels (coal, crude oil, natural gas) are.
- Describe the processes involved in the issuing of a mineral exploration license.
- Describe the processes involved in mineral prospecting and drilling.
- Describe the processes involved in the issuing of oil and gas exploration license.
- Describe the processes involved in oil and gas drilling, logging, reserve estimate and well completion.
- Describe the environmental regulations related to mineral and fossil fuel extraction and production.
- Describe the different environmental policies on mining and fossil fuel extraction.
- Describe mine closure plan and environment rehabilitation after mine closure.

Performance Task

Students will do an assignment out of 50marks. You can use other assessment tools (assignment, projects, etc.) assess student's proficiency on these benchmarks.

Assessment Strategy

Assignment will be used to measure student's proficiency.

Assessment Tool

An assignment will be used to measure students' proficiency.

Assessment Scoring

Rubrics must be developed to articulate the real proficiency of the child. This is an analytical rubrics used to assess the child's learning through the assessment tool an assignment.

Performance standards/ Criteria	A Advance 50	B Proficient 49 - 30	C Progressing 29-10	D Not Yet 9-0	Score __/50 Marks
Explain the difference between economic and industrial minerals. *(5 marks)*	Exceptional detailed, clear and succinct explanation of the difference between economic and industrial minerals	Good clear explanation of the difference between economic and industrial minerals	Fair and satisfactory explanation of the difference between economic and industrial minerals	Explanation of the difference between economic and industrial minerals is poor and vague.	
Use a segmented process chart to explain the processes involved in the issuing of a mineral exploration license. *(15 marks)*	Detailed segmented process chart showing all the process of issuing mineral exploration license with clear, detailed explanation	Good segmented process chart showing some of the process of issuing mineral exploration license with clear, explanation	Satisfactory segmented process chart showing few of the process of issuing mineral exploration license with vague, explanation	Poor segmented process chart showing of issuing mineral exploration license with clear, no explanation at all	
Use pictorial chart to show the processes involved in mineral prospecting and drilling. *(15 marks)*	Detailed, clear, step by step pictorial chart showing the processes involved in mineral prospecting and drilling with correct headings	Clear, step by step pictorial chart showing the processes involved in mineral prospecting and drilling with some correct headings.	Inconsistencies in the steps of pictorial chart showing the processes involved in mineral prospecting and drilling with few correct heading Inconsistencies in the steps of pictorial chart showing the processes involved in mineral prospecting and drilling with few correct heading	Vague in the steps of pictorial chart showing the processes involved in mineral prospecting and drilling with no correct heading	
For each stage of the process, explain how oil and gas exploration licenses are issued. *(5 marks)*	Exceptional detailed, clear and succinct explanation of how oil and gas licenses are issued	Good clear explanation of explanation of how oil and gas licenses are issued	Fair and satisfactory explanation of explanation of how oil and gas licenses are issued	Explanation of explanation of how oil and gas licenses are issued is poor and vague.	
Explain the environmental regulations related to mineral and fossil fuel extraction and production. *(10 marks)*	Detailed, clear explanation of how environmental regulations related to mineral and fossil fuel extraction and production.	Good clear explanation of explanation of how environmental regulations related to mineral and fossil fuel extraction and production.	Fair explanation of how environmental regulations related to mineral and fossil fuel extraction and production.	Unsatisfactory explanation of how environmental regulations related to mineral and fossil fuel extraction and production.	

Recommended Resources:

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- http://www.OilScams.org
- Internet
- PNG OresomeResources.com – Minerals and Energy Education

Sample 3 : Authentic Assessment

Strand 2: Earth Science
Unit 1: Earth Resources

Content Standard 12.2.1 Students will be able to trace the origins of Earth resources including the deposition of minerals, coal, petroleum, and natural gas, and their economic development and the regulations relating to the environment in which they are operating in

Benchmark 12.2.1.1-12.2.1.5: (refer to the benchmarks in Unit1 Strand 2)

Topics: (refer to the topics in Unit 1 of this Strand)

Lesson topics: (refer to the topics in the Unit: Earth Resources, Strand 2)

Instructional Objective (s): (refer to the topics in Unit: Earth Resources)

What is to be assessed? - (KSAVs)
The essential knowledge, skills, attitudes and values in the unit: 'Earth Resources'

Purpose of the assessment
To measure students proficiency on the achievement of the benchmarks and learning objectives in this unit. This assessment is to be conducted after teaching this unit.

Expected level of proficiency
All students are expected to;

- Describe the environmental regulations related to mineral and fossil fuel extraction and production
- Describe the different environmental policies on mining and fossil fuel extraction
- Describe mine closure plan and environment rehabilitation after mine closure

Performance Task
Students will do a project out of 30 marks. You can use other assessment tools (assignment, simulation, interview etc) assess students proficiency on these benchmarks.

Task: Students will be given two weeks to complete this project then carry out awareness.

1. Research information on;
    - some of the regulations related to minerals extraction and production extraction

- different environmental policies on mining extraction

2. They will make presentation on these rights during assembly, recess and lunch time. (Students will be grouped into 5-6 students per group)
3. The best presentation will be given a chance to make presentation in public in their local community.

The aim of this project is to develop students to do research and analyse the information and present to the class. The students will do oral presentation based on this project assignment.

Assessment Strategy

A project will be used to measure student's proficiency.

Assessment Scoring

Rubrics will be developed to find out the real proficiency of the child. This is an analytical rubrics used to assess s the child's learning through the assessment tool a project.

Performance standards/ Criteria	**A**	**B**	**C**	**D**	**Score**
	Advance 30-25	**Proficient 24- 20**	**Progressing 19-10**	**Not Yet 9-2**	**__/30 Marks**
Explain the regulations related to mineral extraction and production *(10marks)*	Very clear, logical explanations on regulations related to mineral extraction and production	Very good explanations on regulations related to mineral extraction and production	Satisfactory explanation of the key words and fair explanations covering regulations related to mineral extraction and production	Poor explanations on regulations related to mineral extraction and production	
Explain the different environmental policies on mining extraction *(10 marks)*	Very clear, logical explanations on different environmental policies on mining extraction	Very good explanations on different environmental policies on mining extraction	Satisfactory explanation of the key words and fair explanations covering different environmental policies on mining extraction	Poor explanations on different environmental policies on mining extraction	
Presentation of finding as an awareness in the school *(10 marks)*	Work presented is clear on the chart, oral presentation is loud and clear and confidence is clearly portrayed	Good presentation of the awareness, that is poster was logic but oral presentation and confidence were moderate	Fair presentation of the awareness, that is poster had few inconsistency on the findings and oral presentation and confidence was fair	Poor presentation of the awareness, poster work was oral presentation was inaudible and general lack in confidence during presentation	

Recommended Resources:

- Davies, H.L., 2013. Earth Tok, 3rd Edition, Alan Caudel & Associates, 351p
- http://www.ispatguru.com/natural-gas-its-characteristics-and-safetyrequirements/
- http://www.OilScams.org
- Internet
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Sample 4 : STEAM Assessment

(Integrated Strands in relation to the project from integrated subjects)

Unit: (Integrated Units from all Subjects in this project)

Content Standard: (Integrated Content Standard from all Subjects in project)

Benchmark: (Integrated Benchmarks from all Subjects in this project)

Topic: (Integrated Topics from all Subjects in this project)

Lesson topic: (Integrated Topics from all Subjects in concern)

Instructional Objective (s): Students will be able to;

- Create a STEAM project "building a prototype model of a catapult launching system" to enhance their understand of this concept

VASK-MT	
Values/Attitudes	Appreciate the beauty of the application of mathematics during the designing process of the project.
Skills	Calculating size and space Time management and efficiency, Linear measurement and scaling techniques, Calculating mechanical advantage
Knowledge	Size and space Time management and efficiency, Linear measurement and scaling techniques
Mathematical Thinking	Think about how to integrate and apply the mathematical knowledge in the project

What is to be assessed? - (KSAVs)

Integrated subjects concepts used designing the projects.

Purpose of the assessment

To measure students proficiency on the achievement of the benchmarks and learning objectives for integrated subjects in the project. (STEAM Project)

Expected level of proficiency

All students are expected to:

- Build a prototype model of a catapult launching system through integrating concepts learned in other subjects.

Performance Task

Student will carry out a project worth 30 marks that should contribute to the School Learning Improvement Program (SLIP). This project will assess students proficiency on the mentioned benchmarks. In order for this assessment type to attain its intended purpose the following must be done carefully;

Task: Students will be given a month to complete this project.

1. All grade 12 Science teachers discuss the STEAM project with their HOD
2. The Science HOD brings this project to the attention of the Head Teacher hence it will involve the learning of all grade 12 classes in the school.
3. Once approved by the Head Teacher, the Science HOD now convenes a meeting with all other subject HOD to integrate this project into their learning. HOD for Science will have developed criteria already and will discuss around that.
4. The HOD for other subjects meet with their respective subject teachers to gauge their views and write up criteria's with reference to the theme of the project, "STEM Design and Engineering Challenge" bringing out the essence of their subjects in this project.
5. The Head Teacher then convenes a meeting with all teachers as they are now aware of the project. HOD for respective subjects give feedback from their meetings. Issues concerning this project must be ironed out and all subjects now carry out this assessment, starting with Science.

The grade 12 Science teachers will now do the following;

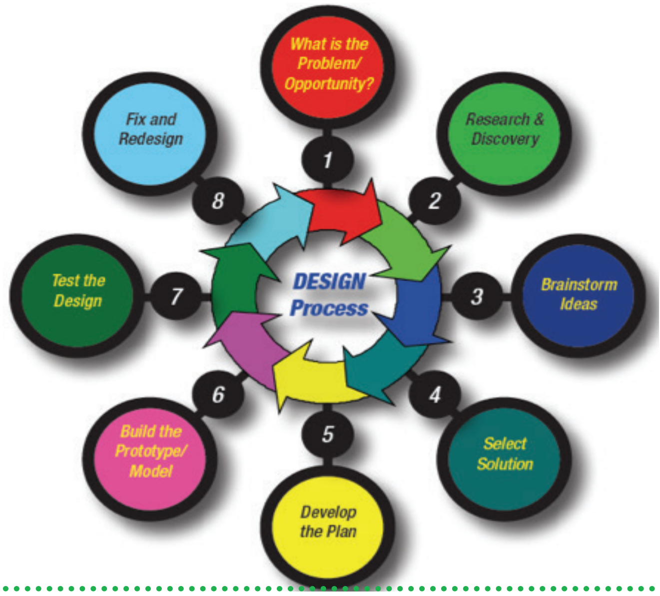
(i) Group the students into groups of 6 to design (drawing and manual) a tangible technology that will enhance the notion of "building a prototype model of a catapult launching system"

(ii) The teacher then assesses their designs and the best designs now compete with the other best designs from other grade 12 classes.

(iii) All the best designers now create models of their designs with assistance from their class members. At this stage the other subjects now carry forward this assessed projects theme, 'building a prototype model of a catapult launching system" however in the context of their subjects. STEAM is an integrated approach of teaching. All subjects must incorporate the theme put forward by Science. They develop criteria that should address this theme. For instance; Technology and Industrial Arts (TIA) will develop criteria that will engage the students to construct the models. Mathematics teachers will develop criteria to test students' knowledge of the Mathematical thinking process of Engineering Design thinking when they create the models around the theme of "prototype model of a catapult launching system". The English subject teachers will set criteria and guidelines for students on how to write reports so they write to tell others what they have learned and experienced. They must also be given guidelines to writing report. Students get to write report of how they designed this technology. The Science teacher will provide criteria for the students in terms of the physical, chemical, biological and geological properties of the materials used to work out the size and shape of the technology.

Task: Students will be given 6 weeks to complete this project. They are to;

- Design and build a prototype model of a catapult launching system that is easy to use and easy to transport.
- Follow the Design Process to prepare their prototype model in time.
- Write and prepare a short presentation to explain the catapult that was built and the process of building it.



Design Specification:

The catapult should be designed to launch a golf ball at least fifteen feet, to a 18cm x 18cm target.

- The catapult should include a system for determining range, reliability, and accuracy.
- The catapult should be mobile, yet stable. Outriggers or other support systems need to be included to maintain stability when the launcher is used.
- The catapult should be no larger than 30cm long x 30 cm deep x 90cm tall.
- The catapult should feature a locking pin or trigger that activates the catapult to launch.
- Your team should prepare to deliver a presentation about the merits of your catapult model and design.

Assessment Strategy

Design Project will be used to measure student's proficiency.

The students will be reinforced in the following STEAM concepts.

Science

- Applications of simple machines, including wheels and axles, levers, and pulleys
- Balance and equilibrium
- Energy transformations, such as rotary motion to linear motion
- Mechanical advantage

Technology and Engineering

- Prototyping and modelling
- Invention and innovation
- Structural integrity/strength
- Brainstorming and problem solving
- Trial and error engineering concepts

Arts

- Sketching and painting

Mathematics

- Calculating size and space
- Time management and efficiency
- Linear measurement and scaling techniques
- Calculating mechanical advantage

Project Rubric

Category	Advanced	Satisfactory	Partial Credit	Unacceptable
	9 -10 points	7- 8 points	1 - 6 points	0 points
Quality/ Workmanship	Maximum effort was put forth to complete the project in a professional manner. Project demonstrates a high degree of quality and attention to detail. Workmanship is excellent.	Some effort was made to complete the project to a level that was sufficient for grading, but does not meet a professional level of quality or appearance. Workmanship is of acceptable quality.	Minimal effort was made to complete the project and the quality and workmanship is sub-par, but still meets the minimal standard.	Little or no effort was made to produce a quality project. Project obviously does not meet minimal standards.
Creativity/ Design	Project reflects many fundamental elements of design and creativity. Project demonstrates an advanced understanding of creative thinking and attention to aesthetics and presentation.	Project reflects some of the elements of design and creativity, but lacks attention to aesthetics and presentation.	Project was completed, but does not reflect the acceptable levels of design and creativity. Effort was minimal and project is mediocre at best.	Project was not completed on time or reflects little or no effort to complete assignment at an acceptable level.
Functionality	Project meets or exceeds the design requirements of purpose and functionality. All elements of the design have been met and the project does what it was designed to do.	Project meets some of the design requirements of purpose and functionality. Not all elements of the design have been met, but the project does what it was designed to do.	Project is somewhat functional, but reflects minimal effort. It is intermittent and doesn't always do what it was designed to do.	Project does not work and demonstrates a lack of effort or understanding of the basic elements of functionality and purpose.
Design Process	Project reflects a clear understanding and application of design process including evidence of research, brainstorming, design and problem solving, prototyping and testing.	Project reflects some understanding and application of accepted design loop principles and sequence including evidence of research, brainstorming, design and problem solving, prototyping and testing.	Project reflects minimal understanding and application of design process.	Project does not show evidence that design process was used. Project does not meet accepted levels of design criteria.
Criteria/ Constraints	Project was completed with all constraints and criteria met or exceeded. Reflects attention to detail and quality.	Project was completed with some of the constraints and criteria met. Reflects some attention to detail, but quality is minimal.	Project was completed with a few of the constraints and criteria met. Reflects minimal effort and lacks detail or quality.	Project was not completed and does not reflect the adherence to the constraints or criteria.

Time Management	Project completed and turned in on time. Student worked diligently when project time was available. Student was on task most of the time.	Project was completed, but had notable errors. Student utilized project time somewhat efficiently, but spent time socializing. Student was on task 70% - 80% of the time.	Project was not turned in on time and/or complete. The student was on task less than 60% of the time.	Project was not turned in on time and was not completed. Student wasted project time and at times was disruptive to others.
Resource Management	Always takes responsibility for use and care of all building components and resources. Always returns building components and materials to proper storage compartments.	Consistently takes responsibility for use and care of building components and resources. Somewhat consistent in returning building components to proper storage compartments.	Sometimes takes responsibility for use and care of building components and resources. Inconsistent in returning building components to proper storage compartments.	Does not take responsibility for the proper use and care of building components and resources. Is careless and does not practice proper storage and safety practices.
Teamwork	Notable teamwork shown with a determination to participate/contribute to team success. Completed required individual tasks that contributed to the success of the team.	Teamwork was noted, but was sometimes off task or working on non-related tasks. Contributed to the success of the team, but could have been more engaged to complete tasks sooner.	Notable time off-task with minimal effort given for team success, or did the project alone without relying on others to do their share of the project.	Was not a team player. Either took over project completely, or did not engage in team direction or plans.
Writing/ Reflection	Writing/reflection is very well organized and explained. Student includes all details in design process. Document has almost no grammatical errors.	Writing/reflection is somewhat organized and explained. Student includes most details in design process. Document has very few grammatical errors.	Writing/reflection is not organized and explained. Student includes only a few details in design process. Document has many grammatical errors.	Writing/reflection is incomplete or not turned in. Student includes no details in design process. Document has many grammatical errors.
Presentation	Presentation was well organized and presented in a logical sequence. Presentation reflects a full knowledge of the topic with clear answers and explanations to questions asked.	Presentation was fairly organized and most information presented in a logical sequence. Answers to questions were vague or lacked clarity or accuracy.	Presentation was unorganized and lacked a logical sequence. Presentation reflected little attention to detail. Answers to questions were inaccurate and confusing.	Presentation was not acceptable and reflects a lack of organization or knowledge of the topic. Presentation shows little effort to meet expectations.

Checklist

Checklists contain lists of behaviours, traits or characteristic that can be scored on a **yes/no**, **present/absent or 0/1 basis**. Checklist is similar to rating scales however the basic difference between them is the judgement needed.

- checklist = yes/no
- rating scale = one has to indicate the degree to which a character is present or the frequency with which a behaviour occurs.

To obtain the most information possible observers need to develop a checking system which is organised, easy to use and time efficient.

Sample Checklist
Topic: Geological Equipment
Hand Lens – Task: Procedures of using a hand lens correctly

Checklist: Place a tick in the following boxes.

Correct steps to using a Hand Lens	Yes	No
Correctly, take your lens in whatever hands feel more natural. This will usually be the one for your dominant eye.		
Correctly, take the rock in the other hand; position yourself, so that there is a strong light source shining over your shoulder onto the rock.		
Correctly, bring the rock towards you until the details become sharp and clear.		
Correctly, move and twist the rock around a little to get use to holding it steady and to get familiar with the rock.		
Correctly, move and twist the rock around a little to get use to holding it steady and to get familiar with the rock.		

Rating Scale
Rating Scales are a type of checklist that judge the degree to which a criteria is met. So they often use a rating scale. They generally have a scale of between 1-6 options.

Types of Rating Scales
1. Frequency Rating Scale (Consistency) e.g. Always, Sometimes, Rarely, Never
2. Grade Rating Scale. i.e. A, B, C, D
3. Number scales, e.g. Not all true Very true
   1 2 3 4 5

Like checklists they are easy to administer, develop and understand although they are more subjective. They are very effective for peer assessment activities which measures one criteria or performance standard at a time.

Glossary

Words	Definition
Aa	A term of Hawaiian origin. Used in reference to a basaltic lava that occurs in flows with a fissured, rough and jagged surface.
Abrasion	Is the process by which a stream's irregular bed is smoothed by the constant friction and scouring impact of rock fragments, gravels, and sediment carried in the water.
Absolute age dating	The geologic age of a fossil organism, rock, or geologic feature or event given in units of time, usually years.
Alluvial mine	It is the mining of stream bed deposits (also known as alluvial deposits) for minerals. These alluvial deposits are formed when minerals are eroded from their source, and then transported by water to a new locale.
Aquifer	A subsurface rock or sediment unit that is porous and permeable. To be an aquifer it must have these traits to a high enough degree that it stores and transmits useful quantities of water.
Aquifer (artesian)	An aquifer that is bounded above and below by impermeable rock or sediment layers. The water in the aquifer is also under enough pressure that, when the aquifer is tapped by a well, the water rises up the well bore to a level that is above the top of the aquifer. The water may or may not flow onto the land surface.
Aquifer (confined)	An aquifer that is bounded above and below by impermeable rock or sediment layers. There may or may not be enough pressure in the aquifer to make it an “artesian aquifer”.
Aquifer (unconfined)	An aquifer that is not overlain by an impermeable rock unit. The water in this aquifer is under atmospheric pressure and is recharged by precipitation that falls on the land surface directly above the aquifer.
Attrition	Is a form of coastal or river erosion, when the bed load is eroded by itself and the bed. As rocks are transported downstream along a riverbed, the regular impacts between the grains themselves and between the grains and the bed cause them to be broken up into smaller fragments.
Avalanche	A mass of material moving rapidly down a slope. An avalanche is typically triggered when material on a slope breaks loose from its surroundings; this material then quickly collects and carries additional material down the slope.
Basalt plateau	A term applied to those basaltic lavas that occur as vast composite accumulations of horizontal or subhorizontal flows, which, erupted in rapid succession over great areas, have at times flooded sectors of the Earth's surface on a regional scale.
Biological weathering	Is the weakening and subsequent disintegration of rock by plants, animals and microbes.
Body waves	A body wave is a seismic wave that moves through the interior of the earth, as opposed to surface waves that travel near the earth's surface. P and S waves are body waves. Each type of wave shakes the ground in different ways.
Caldera	A large, bowl-shaped crater associated with a volcanic vent. A caldera can form from a volcanic blast or the collapse of a volcanic cone into an emptied magma chamber.

Words	Definition
Chemical weathering	The breaking down of surface rock material by solution or chemical alteration. Common alteration processes are oxidation and hydrolysis.
Cinder cone	Also called ash cone, deposit around a volcanic vent, formed by pyroclastic rock fragments (formed by volcanic or igneous action), or cinders, which accumulate and gradually build a conical hill with a bowl-shaped crater at the top.
Compass -clinometer	Compass clinometers are fundamentally just magnetic compasses held with their plane vertical so that a plummet or its equivalent can point to the elevation of the sight line. The clinometer measures the dip of a bedding plane with respect to the horizontal.
Colluvium	Colluvium (also colluvial material or colluvial soil) is a general name for loose, unconsolidated sediments that have been deposited at the base of hillslopes by either rain-wash, sheet-wash, slow continuous downslope creep, or a variable combination of these processes.
Composite cone	A cone-shaped volcanic mountain composed of alternating layers of cinders and lava flows. Also known as a stratovolcano.
Concentrating	Is one of the processes required for converting an ore body into sellable metal. Most ores are usually bound to other elements, most commonly sulphur. Other common elements found with metallic minerals include arsenic, antimony, tellurium and even other metals, such as iron.
Creep	Is a slow downslope movement of particles that occurs on every slope covered with loose, weathered material.
Crude oil	Crude oil is a naturally occurring, unrefined petroleum product composed of hydrocarbon deposits and other organic materials. A type of fossil fuel, crude oil can be refined to produce usable products such as gasoline, diesel and various forms of petrochemicals.
Crushing	The process of breaking up large rocks into smaller rocks, gravel or rock dust. Crushing is an essential part of the mining, reducing run-of-mine ore to a size that can be easily transported or processed.
Deposition	Deposition is the geological process in which sediments, soil and rocks are added to a landform or land mass. Wind, ice, water, and gravity transport previously weathered surface material, which, at the loss of enough kinetic energy in the fluid, is deposited, building up layers of sediment.
Disconformity	A disconformity is an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition. Disconformities are marked by features of subaerial erosion.
Dissolution	The process in which solids (like minerals) are disassociated and the ionic components are dispersed in a liquid (usually water).
Earthquake	A trembling of the earth caused by a sudden release of energy stored in subsurface rock units.
Earthquake hazard	Earthquake hazard is anything associated with an earthquake that may affect the normal activities of people. This includes surface faulting, ground shaking, landslide, liquefaction, tectonic deformation, tsunamis, and seiches.
Earthquake risk	Earthquake risk is the probable building damage, and number of people that are expected to be hurt or killed if a likely earthquake on a particular fault occurs. Earthquake risk and earthquake hazard are occasionally incorrectly used interchangeably.

Words	Definition
Economic minerals	The definition of an economic mineral is broader, and includes minerals, metals, rocks and hydrocarbons (solid and liquid) that are extracted from the Earth by mining, quarrying and pumping. Economic minerals include: energy minerals, metals, construction minerals and industrial minerals.
Elastic rebound theory	A theory that explains the earthquake process. In this theory, slowly accumulating elastic strain builds within a rock mass over an extended length of time. This strain is suddenly released through fault movement, producing an earthquake.
Electrolysis	Electrolysis is a simple process using electric voltage and current to separate minerals into metals, oxygen, and any desired oxides. It can also be used to split up a mineral into metal oxides rather than pure metal, e.g., for making special ceramics.
Environment Impact Statement	An Environmental Impact Statement (EIS) is a document prepared to describe the effects for proposed activities on the environment. "Environment," in this case, is defined as the natural and physical environment and the relationship of people with that environment.
Environmental regulation	Refers to the general guidelines, legislation, laws and acts, etc. for the preservation and conservation of the environment at national, regional and city levels.
Epicentre	The point on the Earth's surface directly above the focus of an earthquake.
Erosion	A general term applied to the wearing away and movement of earth materials by gravity, wind, water and ice.
Exploration license	A permit issued by the Government or its agency to people or groups of people to conduct surveys and/or explore for natural resources in a specified area
Faunal succession	A principle of relative dating that is based upon the observed sequence of organisms in the rock record. The relative age of two rock units can frequently be determined by matching the fossils found in those rocks to their positions in the rock record.
Flotation	in mineral processing, method used to separate and concentrate ores by altering their surfaces to a hydrophobic or hydrophilic condition—that is, the surfaces are either repelled or attracted by water.
Fossil fuel	A carbon-rich rock material or fluid, of organic origin that can be produced and burned as a fuel. Coal, oil and natural gas are examples of fossil fuels.
Geologic time	Is the succession of eras, periods, and epochs as considered in historical geology.
Geological hammer	Is a hammer used for splitting and breaking rocks.
Geophysical Survey	Measurements of the magnetic, electrical or other physical characteristics of the Earth as a means to indicate the presence of buried economic mineralisation.
Global Positioning System (GPS)	acronym for Global Positioning System. GPS units are small hand-held devices used to accurately display your position in the bush. Most GPS receivers, by default (factory-set), display latitude-longitude values based on the WGS84 datum. Most existing mapping data reference a local (non-WGS84) datum. Most GPS receivers have built-in datum transform software, and can be re-configured to output data referenced to whatever datum the user requires.

Words	Definition
Graded-Bedding	A rock layer that has a progressive change in particle size from top to bottom. Most common is a sequence with coarse grains at the bottom and fining upwards, which is typically caused by a declining current velocity within the depositional environment.
Groundwater	Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers.
Hazards	A threat (natural or human) that has the potential to cause loss of life, injury, property damage, socio-economic disruption or environmental degradation.
Hydraulic action	Is the erosion that occurs when the motion of water against a rock surface produces mechanical weathering. Most generally, it is the ability of moving water (flowing or waves) to dislodge and transport rock particles.
Industrial mineral	Industrial resources (minerals) are geological materials which are mined for their commercial value, which are not fuel (fuel minerals or mineral fuels) and are not sources of metals (metallic minerals) but are used in the industries based on their physical and/or chemical properties.
Isotope	One of several forms of an element. These different forms have the same number of protons but varying numbers of neutrons.
Lahar	A mudflow composed of water and volcanic ash. Lahars can be triggered by the flash melting of the snow cap of a volcanic mountain or from heavy rain. Lahars are very dangerous because they can occur suddenly and travel at great speeds.
Landslide	A downslope movement of rock and soil over a failure surface and under the influence of gravity. Slumps, earthflows, debris flows and debris slides are examples.
Lava	Molten rock material on Earth's surface.
Love wave	A Love wave is a surface wave having a horizontal motion that is transverse (or perpendicular) to the direction the wave is traveling.
Magma	Molten rock material that occurs below Earth's surface.
Magnitude	A measure of earthquake strength based upon the amount of ground motion experienced and corrected for the distance between the observation point and the epicentre. There are several magnitude scales in use.
Mass movement	A general term used for any downslope movement of rock, soil, snow or ice under the influence of gravity. Includes: landslides, creep, rock falls and avalanches. Also known as mass wasting.
Modified Mercalli Intensity Scale	The intensity is a number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale. There are many intensities for an earthquake, depending on where you are, unlike the magnitude, which is one number for each earthquake.
Mine closure plan	Involves planning effectively for the after-mining landscape – all activities required before, during, and after the operating life of a mine that are needed to produce an acceptable landscape economically. Closure performance refers to the activities near and after mine closure and how well activities listed in the closure plan are carried out.

Words	Definition
Mineral prospecting	Prospecting is the first stage in the utilization of a mineral deposit, is the search for ores or other valuable minerals (coal or non-metallic). Because mineral deposits may be located either at or below the surface of the earth; both direct and indirect prospecting techniques are employed.
Mineral Reserve	The economically mineable part of a Measured or Indicated Mineral Resource demonstrated by at least a Preliminary Feasibility Study. This Study must include adequate information on mining, processing, metallurgical, economic and other relevant factors that demonstrate, at the time of reporting, that economic extraction can be justified. A Mineral Reserve includes diluting materials and allowances for losses that may occur when the material is mined.
Mineral Resource	A concentration or occurrence of diamonds, natural solid inorganic material, or natural solid fossilized organic material including base and precious metals, coal, and industrial minerals in or on the Earth's crust in such form and quantity and of such a grade or quality that it has reasonable prospects for economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge.
Natural Gas	Naturally occurring hydrocarbons that exist in subsurface rock units in the gaseous state. Methane is the most abundant but ethane, propane and others also occur.
Non-conformity	It is one of the three basic types of unconformities in Geology. In two rocks, the erosional contacts lying parallel to the surfaces of both the rocks are known as a non-conformity.
Nuée ardente	A nuée ardente is a turbulent, fast moving cloud of hot gas and ash erupted from a volcano. They form during explosive eruptions as columns of erupted material collapse or during non-explosive eruptions when volcanic rock collapses.
Open-cut mine	Is a surface mining technique of extracting rock or minerals from the earth by their removal from an open pit or borrow.
Ore	Natural occurring mixture of minerals (or a mineral) that can be mined and sold for a profit, or from which one or more minerals can be profitably extracted.
Pahoehoe	A Hawaiian term for a lava flow that has a surface flow structure appearance that looks like coiled rope or cord. See aa for contrast.
Petrographic microscope	A petrographic microscope is a type of optical microscope used in petrology and optical mineralogy to identify rocks and minerals in thin sections. The microscope is used in optical mineralogy and petrography, a branch of petrology which focuses on detailed descriptions of rocks.
Physical weathering	A general term applied to a variety of weathering processes that result in the particle size reduction of rock materials with no change in composition. Frost action, salt crystal growth and pressure relief fracturing are examples. Also known as mechanical weathering.
Pillow lava	Lava in the form of an agglomeration of rounded, pillow-shaped masses, the result of subaqueous or subglacial volcanic eruption.
Primary Seismic Waves	The fastest set of earthquake vibrations - also known as P-waves. They move through the Earth in compression and expansion motions (much like sound waves move through air). Called primary because they are the first recorded at a seismograph. Primary waves are able to travel through both solids and liquids.
Pyroclastic flows	A pyroclastic flow is a dense, fast-moving flow of solidified lava pieces, volcanic ash, and hot gases. It is extremely dangerous to any living thing in its path.

Words	Definition
Pyroclastic rock	A rock formed when small particles of magma are blown from the vent of a volcano by escaping gas.
Radiometric survey	A land-based or airborne survey, using Spectrometers to measure the intensity of gamma radiation from the surface of the earth with the objective of mapping the distribution of radioactive elements, typically, Potassium, Uranium and Thorium. The measurements are also affected by radionuclides, nuclear fallout, radon in the air, and cosmic radiation. Mineral exploration companies principally use these surveys in the search for buried uranium or thorium deposits and for areas of potassic alteration.
Rayleigh wave	A Rayleigh wave is a seismic surface wave causing the ground to shake in an elliptical motion, with no transverse, or perpendicular, motion.
Relative age dating	The geologic age of a fossil organism, rock, geologic feature, or event, defined relative to other organisms, rocks, features, or events rather than in terms of years.
Remote sensing	The collection of information about an object or area from a distance. Methods employed include photography, radar, spectroscopy and magnetism.
Reserve calculation	Estimates made on the basis of measurements from widely
spaced sampling points and exploratory openings(	Is a surface mining technique of extracting rock or minerals from the earth by their removal from an open pit or borrow.
borehole/ pit/ trenches) with reasonable extrapolation on	Natural occurring mixture of minerals (or a mineral) that can be mined and sold for a profit, or from which one or more minerals can be profitably extracted.
geological grounds.	A Hawaiian term for a lava flow that has a surface flow structure appearance that looks like coiled rope or cord. See aa for contrast.
Richter magnitude scale	A scale that is used to compare the strength of earthquakes based upon the amount of energy released. The scale is logarithmic and an arbitrary earthquake was used as a starting point for creating the scale. As a result it is a continuous scale with no upper limit and negative numbers possible for very small earthquakes. An upper limit of approximately 9.0 is suspected as Earth materials will most likely fail before storing enough energy for a larger magnitude earthquake.
Rift	In geology, a rift is a linear zone where the lithosphere is being pulled apart and is an example of extensional tectonics.
Saturated zone	Is the area in an aquifer, below the water table, in which relatively all pores and fractures are saturated with water.
Sediment	Sediment is solid material that is moved and deposited in a new location. Sediment can consist of rocks and minerals, as well as the remains of plants and animals. It can be as small as a grain of sand or as large as a boulder. Sediment moves from one place to another through the process of erosion.
Seismic wave	A seismic wave is an elastic wave generated by an impulse such as an earthquake or an explosion. Seismic waves may travel either along or near the earth's surface (Rayleigh and Love waves) or through the earth's interior (P and S waves).

Words	Definition
Seismogram	A seismogram is a record written by a seismograph in response to ground motions produced by an earthquake, explosion, or other ground-motion sources.
Seismograph	A seismograph, or seismometer, is an instrument used to detect and record earthquakes. It generally refers to the seismometer and its recording device as a single unit.
Seismology	Seismology is the study of earthquakes and the structure of the earth, by both naturally and artificially generated seismic waves.
Shield volcano	Shield volcanoes are volcanoes that mainly erupt fluid (usually basaltic) lava flows that are able to travel over long distances and thus construct over time broad, gentle slopes. They are called shield volcanoes, because they resemble the shape of a warriors' shield.
Slump	A slump is a form of mass wasting that occurs when a coherent mass of loosely consolidated materials or rock layers moves a short distance down a slope. Movement is characterized by sliding along a concave-upward or planar surface. Causes of slumping include earthquake shocks, thorough wetting, freezing and thawing, undercutting, and loading of a slope.
Smelting	Smelting is the process of melting ores and removing the impurities. The resulting product is pure metal.
Solifluction	Is the flow of water saturated earth material over an impermeable surface such as permafrost. It occurs frequently in bitterly cold regions such as in Alaska or Canada.
Stratigraphy	The study of sedimentary rock units, including their geographic extent, age, classification, characteristics and formation.
Strike	The geographic direction of a line created by the intersection of a plane and the horizontal. Often used to describe the geographic “trend” of a fold or fault.
Strike-Slip Fault	A fault with horizontal displacement, typically caused by shear stress.
Strip mine	Consists of stripping surface layers off to reveal ore/seams underneath; and mountaintop removal, commonly associated with coal mining, which involves taking the top of a mountain off to reach ore deposits at depth.
Submarine mass movement	Is the process responsible for redepositing large volumes of sediments from the upper slopes and the outer shelves into the deep ocean basins.
Surface waves	A surface wave is a seismic seismic wave that is trapped near the surface of the earth.
S-wave	Secondary seismic waves. A seismic wave with a direction of vibration that is perpendicular to the direction of travel. S-waves are slower than P-waves and travel only through solids.
Tailings	Washed or milled ore that is too poor to be further treated.
Talus	An accumulation of angular rock debris at the base of a cliff or steep slope that was produced by physical weathering.
Trap	A sedimentary or tectonic structure where oil and/or natural gas has accumulated. These are structural highs where a porous rock unit is capped by an impermeable rock unit. Oil and gas trapped within the porous rock unit migrate to a high point in the structure because of their low density.

Words	Definition
Turbidity current	Also termed density current. A mixture of sediment particles and water that flows down the continental slope. These high density currents can reach great speeds and generally erode loose sediments from the seafloor beneath them.
Underground mine	Refers to various underground mining techniques used to excavate hard minerals, usually those containing metals such as ore containing gold, silver, iron, copper, zinc, nickel, tin and lead.
Uniformitarianism	A basic geologic principle. Processes that act upon the Earth today are the same processes that have acted upon it in the past. The present is the key to the past.
Unsaturated zone	This is the portion of the subsurface above the water table. The soil and rock in this zone contains air as well as water in its pores.
Volcano	A vent in Earth's surface through which molten rock and gases escape. The term also refers to deposits of ash and lava which accumulate around this vent.
Volcanic Ash	Sand-sized particles of igneous rock that form when a spray of liquid magma is blown from a volcanic vent by escaping gas.
Volcanic Ash Fall	An accumulation of volcanic ash produced by an eruption. These can be very thick near the vent and decrease to a light dusting in a downwind direction.
Volcanic Bomb	A projectile of hot magma or rock that is blown from the vent during a volcanic eruption. These solidify in flight and frequently form an elongated rock of streamlined shape.
Volcanic Cone	A cone-shaped hill or mountain composed of pyroclastic debris and/or lava which builds up around a volcanic vent during eruptions.
Volcanic Dome	A steep-sided extrusion of very viscous lava that is squeezed from a volcanic vent without major eruption. These are frequently rhyolitic in composition and produce a rounded mound above the vent.
Water Quality	An assessment of the physical, chemical and biological characteristics of water, especially how they relate to the suitability of that water for a particular use.
Water Table	A level beneath the Earth's surface, below which all pore spaces are filled with water and above which the pore spaces are filled with air. The top of the zone of saturation in a subsurface rock, soil or sediment unit.
Weathering	Process by which Earth materials change when exposed to conditions at or near the Earth's surface and different from the ones under which they formed.

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Appendices

Appendix 1: Bloom's Taxonomy

LEVEL OF UNDERSTANDING	KEY VERBS
CREATING Can the student create a new product or point of view?	Construct, design, and develop, generate, hypothesize, invent, plan, produce, compose, create, make, perform, plan, produce, assemble, formulate,
EVALUATING Can the student justify a stand or decision?	Appraise, argue, assess, choose, conclude, critique, decide, defend, evaluate, judge, justify, predict, prioritize, provoke, rank, rate, select, support, monitor,
ANALYSING Can the student distinguish between the different parts?	Analysing, characterize, classify, compare, contrast, debate, criticise, deconstruct, deduce, differentiate, discriminate, distinguish, examine, organize, outline, relate, research, separate, experiment, question, test,
APPLYING Can the student use the information in a new way	Apply, change, choose, compute, dramatize, implement, interview, prepare, produce, role play, select, show, transfer, use, demonstrate, illustrate, interpret, operate, sketch, solve, write,
UNDERSTANDING Can the student comprehend ideas or concepts?	Classify, compare, exemplify, conclude, demonstrate, discuss, explain, identify, illustrate, interpret, paraphrase, predict, report, translate, describe, classify,
REMEMBERING Can the student recall or remember the information?	Define, describe, draw, find, identify, label, list, match, name, quote, recall, recite, tell, write, duplicate, memorise, recall, repeat, reproduce, state,

Appendix 2: 21st Century Skills

WAYS OF THINKING	Creativity and innovation Think creatively Work creatively with others Implement innovations Critical thinking, problem solving and decision making Reason effectively and evaluate evidence Solve problems Articulate findings Learning to learn and meta-cognition Self-motivation Positive appreciation of learning Adaptability and flexibility
WAYS OF WORKING	Communication Competency in written and oral language Open minded and preparedness to listen Sensitivity to cultural differences Collaboration and teamwork Interact effectively with others Work effectively in diverse teams Prioritise, plan and manage projects
TOOLS FOR WORKING	Information literacy Access and evaluate information Use and manage information Apply technology effectively ICT literacy Open to new ideas, information, tools and ways of thinking Use ICT accurately, creatively, ethically and legally Be aware of cultural and social differences Apply technology appropriately and effectively
LIVING IN THE WORLD	Citizenship – global and local Awareness and understanding of rights and responsibilities as a global citizen Preparedness to participate in community activities Respect the values and privacy of others Personal and social responsibility Communicate constructively in different social situations Understand different viewpoints and perspectives Life and career Adapt to change Manage goals and time Be a self-directed learner Interact effectively with others

Appendix 3: Standards-Based Lesson Plan Template

Standards-Based Lesson Plan (Integrating STEAM)

Topic:

Lesson Topic:

Grade:

Length of Lesson:

National Content Standard

Grade Level Benchmark

Essential Knowledge, Skills, Values, and Attitudes

Knowledge:

Skills:

Values:

Attitudes:

Materials:

- **Lesson Objective:**

Essential Questions:

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
Body	
Guided Practice	
Independent Practice	
Conclusion	

Performance Assessment and Standards

<table>
<tr><td colspan="5">National Content Standard :</td></tr>
<tr><th>Lesson Topic</th><th>Topic</th><th>Benchmark</th><th colspan="2">Performance Assessment</th></tr>
<tr><td rowspan="4"></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">PROFICIENCY RUBRIC</td></tr>
<tr><td>Advanced</td><td>Proficient</td><td>Partially Proficient</td><td>Novice</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

Appendix 4: Standards-Based Lesson Plan Template-Integrating STEAM

Standards-Based Lesson Plan (Integrating STEAM)

Topic:
Lesson Topic:
Grade:
Length of Lesson:

National Content Standard

Grade Level Benchmark

Essential Knowledge, Skills, Values, and Attitudes

Knowledge:

Skills:

Values:

Attitudes:

STEAM Knowledge and Skill

Knowledge:

Skill:

Performance Indicator:

STEAM Performance Indicator:

Materials:

- **Lesson Objective:**

Essential Questions:

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
Body	
Modelling	
Guided Practice	
Independent Practice	
Conclusion	

Performance Assessment and Standards

National Content Standard :				
Lesson Topic	**Topic**	**Benchmark**	**Performance Assessment**	
	PROFICIENCY RUBRIC			
	Advanced	**Proficient**	**Partially Proficient**	**Novice**

STEAM Activity

Students create a model of a mine that is going to be closed soon shown in the plan and the natural environment that is worth rehabilitating using the values of common good, sustainability, and interdependence; and the attitudes of caring, responsible, and respect.

Appendix 5: Time Allocation

Grade 9 and 10	No. Ln/wk	Min/week	Gr 11 and 12	No. Ln/wk	Min/week
English	6	6 x 40=240	Applied English	6	6 x 40 = 240
Mathematics	5	8 x 40 = 320	L &L	6	6 x 40 = 240
Science	5	5 x 40 =200	Advance Math	8	8 x 40 = 320
Social Science	5	5 x 40 =200	Gen Math	6	6 x 40 = 240
Personal Development	5	5 x 40 =200	Physics	6	6 x 40 = 240
Business Studies	5	5 x 40 =200	Biology	6	6 x 40 = 240
Design & Technology	5	5 x 40 =200	Chemistry	6	6 x 40 = 240
Arts	5	5 x 40 =200	Applied Science	6	6 x 40 = 240
CCVE	3	3 x 40=120	Geology	**6**	**6 x 40 = 240**
RI	1	1 x 60 = 60	Geography	6	6 x 40 = 240
Agriculture	5	5 x 40 = 200	History	6	6 x 40 = 240
			Legal Studies	6	6 x 40 = 240
			Health Phy. Educ.	6	6 x 40 = 240
			Physical Educ.	6	6 x 40 = 240
			RE	1	1 x 60 = 60
			Business Studies	6	6 x 40 = 240
			Accounting	6	6 x 40 = 240
			Economics	6	6 x 40 = 240
			Design & Tech	6	6 x 40 = 240
			Computer Studies	6	6 x 40 = 240
			ICT	6	6 x 40 = 240
			CCVE	2	3 x 40 =120
			ANRM	6	6 x 40 = 240