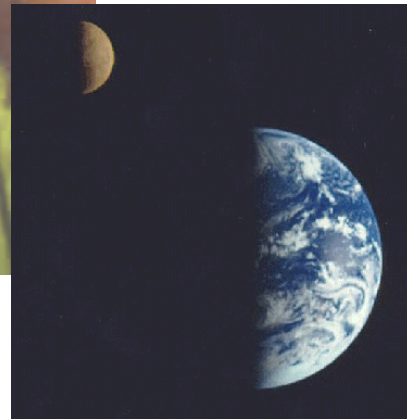


Mathematics Science Strand

Environmental Science

**Environmental
Science**

Lecturers' Guide



Lecturer Support Material

Acknowledgements

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Primary and Secondary Teacher Education Project

Australian Agency for International Development (AusAID)

GRM International

Papua New Guinea-Australia Development Cooperation Program

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Unit overview

Due to changes to the Lower and Upper Primary Syllabuses the content and emphases of some modules have been changed from that originally proposed in Program 2000. As a result the Module *Earth Science* has been divided into two modules – E5 *Earth Science* and E6 *Earth in Space* to provide more study of topics contained in the draft Primary Environmental Science Syllabuses. These modules contain topics to provide coverage of the topics in Program 2000 as well as the draft Syllabuses. The **four core modules** for the Unit ***Environmental Science*** are E1, E2, E5 and E6 while E3, Weather, is only a supplementary module.

You may choose to mix and match the modules to suit local conditions and needs. However the example on the next page shows a recommended sequence in the teaching and learning of the modules.

The sequence and suggested times for teaching the modules are as follows:

E3 Weather and climate

3 hrs

- Water cycle
- Measuring weather
- Weather patterns and climate

E1 Ecology

9 hrs (CORE)

- Distribution and adaptations
- Ecology; food chains; nutrient cycles
- Succession
- Sustainable biological development

E2 Flora and fauna of PNG

9 hrs (CORE)

- Taxonomy of PNG flora and fauna
- Endangered species
- Field techniques and research skills
- Project

E5 Earth Science

9 hrs (CORE)

- Plate tectonics
- Earthquakes
- Volcanoes
- Natural disasters

E6 Earth in Space

9 hrs (CORE)

- Stars and constellations
- Moon and tides
- Sun
- Planets

Links to Primary Syllabuses

It is essential that lecturers keep abreast of the changes in the Primary Syllabuses and modify the Unit content, emphases and teaching programs to reflect these changes.

It is only through a proactive approach to curriculum development and teaching that Primary teachers will be adequately prepared to teach the new Syllabuses.

This table summarises the relationship between the current Program 2000 modules and the draft Primary Syllabuses.

Code	Module/topic	Lower Primary			Upper Primary		
		Yr3	Yr4	Yr5	Yr6	Yr7	Yr8
E1	Ecology	Ö	Ö	Ö	Ö	Ö	Ö
	• Distribution and adaptations					Ö	
	• Ecology; food chains; nutrient cycles	Ö	Ö	Ö	Ö		Ö
	• Succession		Ö				Ö
E2	Flora and Fauna of PNG	Ö	Ö	Ö	Ö	Ö	Ö
	• Taxonomy of PNG flora and fauna					Ö	Ö
	• Endangered species		Ö		Ö	Ö	
	• Field techniques and research skills	Ö	Ö	Ö	Ö	Ö	Ö
E3	Weather and Climate	Ö	Ö	Ö	Ö	Ö	Ö
	• Water cycle	Ö	Ö	Ö		Ö	
	• Measuring weather	Ö		Ö			Ö
	• Weather patterns and climate		Ö		Ö	Ö	Ö
E5	Earth Science	Ö	Ö	Ö	Ö	Ö	Ö
	• Plate tectonics						Ö
	• Earthquakes			Ö		Ö	Ö
	• Volcanoes			Ö	Ö		Ö
E6	Earth in Space	Ö		Ö	Ö		Ö
	• Moon and tides	Ö		Ö			
	• Stars and constellations				Ö		
	• Sun and planets	Ö			Ö		Ö
E6	• Seasons	Ö			Ö		

Teaching program

Example of a teaching program in Environmental Science

Unit: Environmental Science

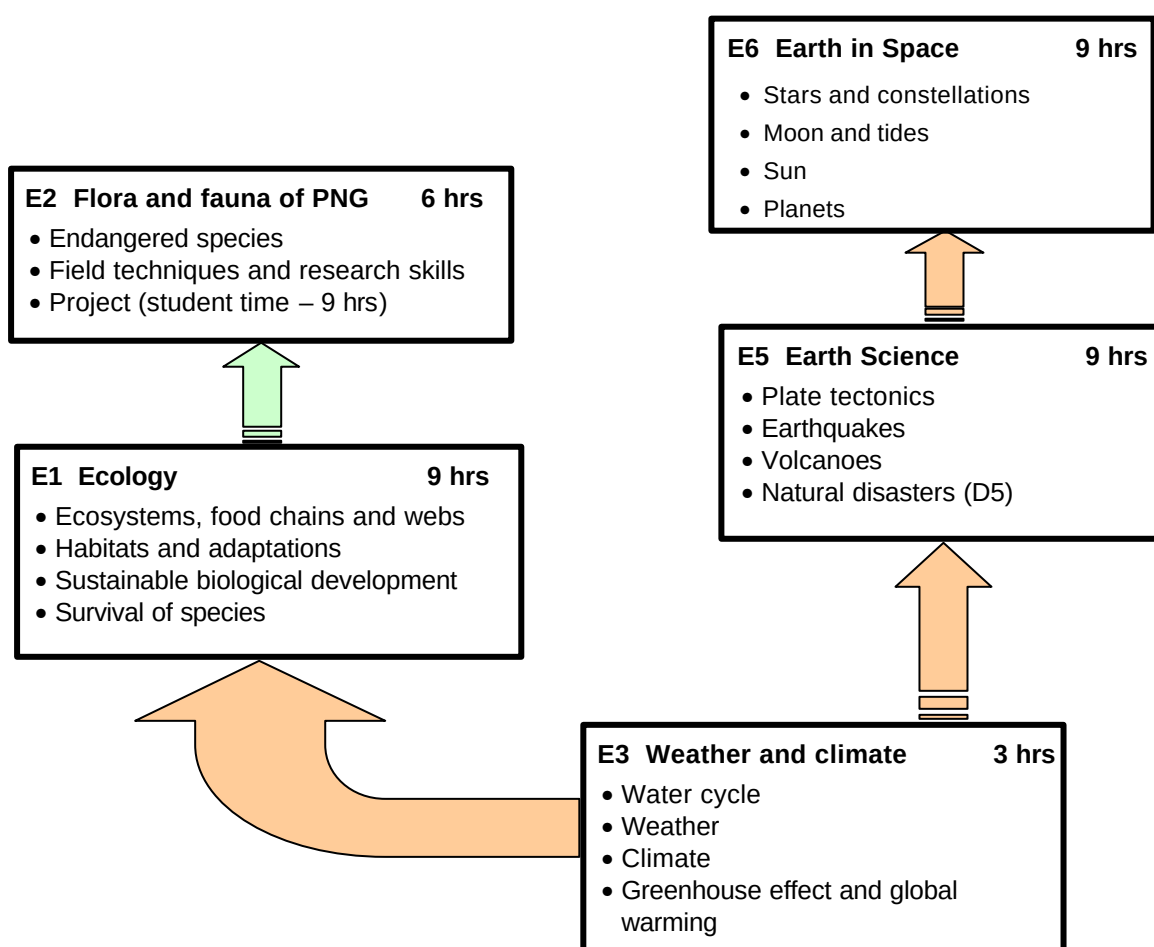
Credit Points: 3 credit points

Class Time: 36 hours (Trimester)

This Unit contains only Environmental Science Modules. The Module E2, Flora and Fauna of PNG, is intended to be done as a Project. Class time would be limited to preparation for the Project therefore less actual class time is allocated.

Other arrangements are also possible however it is important that the recommended sequence is followed. Knowledge of the physical aspects of *Weather and Climate* is essential before studying *Ecology* and *Earth Science*.

These suggested activities are arranged under the main topics in this module. The activities may be used by the lecturer as an introductory activity to gain student interest, to reinforce the concepts or for further development of a topic by students.



Example of a teaching program developed from Environmental Science and Agriculture and Resource Science modules.

Unit: Environmental and Resource Science

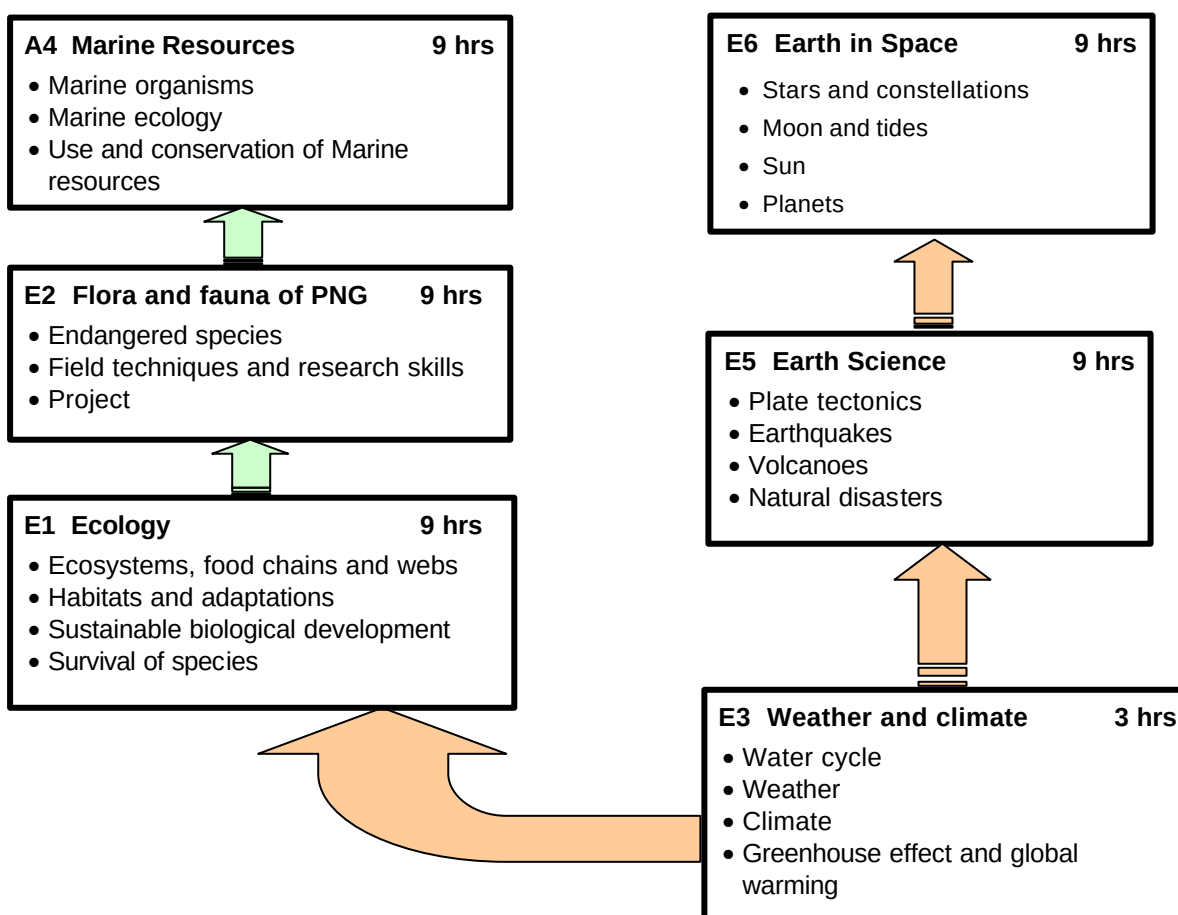
Credit Points: 4 credit points

Class Time: 48 hours (Trimester)

The modules lower in the sequence are pre-requisites of the ones above. For example, the module E1, *Ecology*, must be studied before E2, *Flora and Fauna of PNG*.

To reduce the assessment load on students, assessment items may be designed to integrate more than one unit. For example, in an area where a college has access to the marine environment, an assessment item may consist of a field project based on research in the environment and the report could include the E2 Project. Students may select an endangered species from the sea as part of their field studies.

A sample assessment program has been included.



Approaches to teaching and learning

It is very important that the teaching of science is approached from the personal experience of students. These experiences will provide a real life connection to the important science concepts and the application to PNG situations. Students' prior knowledge and misconceptions about important issues must be established before planning the teaching program.

Student interaction and participation is essential to build on fundamental understandings in science. Practical experiences should be incorporated in the student learning experiences wherever possible. Activities which encourage group debate should form an integral part of the teaching strategies particularly for the modules dealing with resource utilisation.

Local resources should also be utilised for student learning experiences. These resources include the local environments (reef, mangroves, forest), PNG resource materials, NGOs and government bodies.

It also important to ascertain "tambus" in relation to different cultural origins and beliefs before the discussing sensitive issues. Alternative teaching and learning strategies may need to be provided to avoid potential conflict.

Assessment strategies

In keeping with a student-centred approach to teaching and learning it is important that assessment strategies provide opportunity for students to prepare for their professional roles as teachers. Therefore a range of assessment items should be utilised to reflect the teaching approaches and student application to their profession. A list of suggested items has been included but is not exhaustive by any means. Some assessment items may include a number of strategies as a "package". For example, a student may conduct a survey, research his/her findings and assemble a teaching package tailored to local needs. Some examples are:

- Pen and paper examination e.g. multiple choice, short answer and extended answers
- Portfolio e.g., selected tasks completed and submitted by students
- Practical e.g., Activities, investigations and experiments
- Wall charts and posters for teaching science topics – illustrated food chains
- Models e.g., Plate tectonics, volcano models
- Essay e.g., impact of resource harvesting on habitats of PNG
- Diary e.g., own personal reflection on learning
- Personal research e.g., Prior knowledge of science concepts at the village level
- Library and media research e.g., Selected science topics from newspapers; CD – ROMS, library references
- Teaching resources e.g., prepare resource for teaching a science topic
- Survey, e.g., Local knowledge about natural phenomena – weather, volcanoes, sea
- Interview e.g., survey local conceptions about science concepts - moon
- Case studies e.g., collect and collate latest information on a resource extraction or harvesting industry
- Comparative studies e.g., Effects of fishing and mining in other parts of the World

- Stories and cultural beliefs about changes in the environment and space
- Seminar e.g., presentation including posters
- Group projects e.g., Research field project and report – marine, freshwater, lowlands or forest

Sample assessment program

Environmental Science - summative assessment program (4 CP)

There are **five tasks** to be completed for assessment in this unit:

Task	Modules	Item	Week due	%
1	E3 and E1	Written Test	6	20
2	E2 and A4	Fauna and flora Project	10	20
3	A4 and E2	Field Report (team)	10	20
4	All modules	Reflection on learning	13	10
5	E5 and E6	Written Test	13	30

All assignments will be submitted using a College cover sheet. Upon submission, each student will be issued with a receipt, by the lecturer, including the date and items incomplete or missing. Late assignments will only be accepted after interview with the coordinator and production of a satisfactory explanation and/or medical certificate. For any extended periods of illness students may expect an equivalent extension to the due date for any assignment.

Assessment tasks (items)

Task 1	Due Week 6	Worth 20%
---------------	-------------------	------------------

Written test Modules E1 and E3. (Retest, if result unsatisfactory, in Week 8).

Task 2	Due Week 10	Worth 20%
---------------	--------------------	------------------

Flora and fauna of PNG Project Module E2 and A4

This project is to be completed on your own (independent).

- Select one environment or habitat in PNG (forest, lowlands, marine or river). It could be an area near the college or one in your home village.
- Identify the fauna and flora native to the area. Identify relationships and present the links with a diagram of the food webs.
- Through research find out which species in the chosen area are classed as endangered. Your research can be from library resources, local knowledge and expert reports.
- Select **one example** of the endangered species and describe it fully with illustrations.
- Identify the risks (human and natural) on the habitat in which the endangered species is found.
- Propose steps that could be taken to protect the species and the habitat.

Your report may be in **one** of the following formats: (Your choice)

- **Seminar** - oral presentation to the class with summary notes and illustrations submitted.
- **Written report** with illustrations.
- **Poster series** for teaching this topic to a Grade 5 Class.

Task 3	Due Week 12	Worth 20%
---------------	--------------------	------------------

Marine Field Report (Team)	Modules A4 and E2
-----------------------------------	--------------------------

This task is a field investigation that will be conducted as **Teams**. At the lecturer's direction you will form teams of six (6). Pairs within the team will be responsible for the preparation of different sections of the report. **All members of the team are expected to participate in every activity and assist in the gathering of field data.**

Full details of the field activities will be provided the week before the excursion. It will be the responsibility of the assigned pairs to familiarise themselves with the activities for their tasks, collect and make necessary field equipment, and collect additional information prior to conducting the field investigations.

- | | |
|-----------------------------|---------------------|
| Activity 1 (Pair 1): | Transect |
| Activity 2 (Pair 2): | Shore survey |
| Activity 3 (Pair 3): | Reef survey |

Back at the College assigned pairs will be responsible for gathering extra information, interpreting the data and finalising the written report.

The entire report will be bound together presented as one for the team and each pair will be assessed on their contributions.

Task 4	Due Week 13	Worth 10%
---------------	--------------------	------------------

Reflection on learning	All modules
-------------------------------	--------------------

Throughout the semester all students are expected to make notes about their learning difficulties in this unit. A selection of these is to be submitted at the end of semester. Your reflection should be under the following heading:

1. Concepts I had difficulty understanding and the nature of the difficulty.
2. How I clarified my understanding of the concept.
3. How I might have improved my learning.

Task 5	Due Week 13	Worth 30%
---------------	--------------------	------------------

Written test	Modules E5 and E6
---------------------	--------------------------

This test will be the final test for the semester. It will be based on the objectives for the Earth Science and Earth Resources modules. It will contain multiple choice, short answer and extended questions.

Resources

This list provides colleges with recommended resources for the teaching of this unit. College lecturers should continue to keep abreast of changes and the publication of new books and new editions through the relevant booksellers. Those marked with ***** are highly recommended as essential lecturer reading. (Put them on your resource order!).

The following titles are essential and it is highly recommended that colleges add multiple copies of these to their libraries:

Deutrom, B. (1998). *Science for the Pacific: A – Z of Essential Terms*. Oxford: PNG. (ISBN: 0-19-554162-6. Price approx AUD13.00 available from the Co-operative Bookshop).

Cross, R. (1996). *Teaching Primary Science: Empowering children for their world*. Addison Wesley Longman: Melbourne. (ISBN: 0-582-80364-0. Price approx. AUD30.00).

Anderton, J. (Ed). (1999). *Fundamental Science for Melanesia: Books 1, 2, 3 and 4*. Longman. (ISBN: 0 582 72123 7; Approx price each AUD20.00). **This series of books are textbooks used throughout PNG in secondary schools.**

The following CD ROM set is also very useful for both students and lecturers:

Oxford University Press. (2001). *Encyclopaedia Britannica 2001 Deluxe Edn. (CD ROM)*. Oxford University Press: London. (CDDLX01/01: Cost approx. AUD99.00. Available from any good computer software store such as Harvey Norman or Office Works (Price: Approx. AUD90.00).

Ecology and Flora and Fauna of PNG

Some of these titles are also useful for the Module, *Marine Resources*.

Allen, G.R. (1991). *Field Guide to the Freshwater Fishes of New Guinea*. Christensen Research Institute: Madang, PNG. (ISBN: 9980-85-304-2. Available from most dive shops and booksellers in PNG – about Kina 25.00)

Allen, G.R. and Steene, R. (1996). *Indo-Pacific Coral Reef Guide*. Tropical Reef Research: Singapore. (ISBN: 981-00-5687-7; Approx. AUD49.00.).

Allen, G.R. and Swainston, R. (1993). *Reef Fishes of Papua New Guinea*. Christensen Research Institute: Madang, PNG. (ISBN: 9980-9999-0-X. Available from most dive shops and booksellers in PNG – about Kina 10.00).

Coates. (1986). *PNG Birds in Colour*. Robert Brown: Brisbane. (ISBN: 0949267546; Approx price: AUD12.00)

Flannery, T. (1995). *Mammals of New Guinea*. Australian Museum Trust/Reed: Sydney. (ISBN: 0 7301 0411 7). Available from Angus and Robertson. Price approx. AUD40.00

Jones, Robertson, Forbes & Hollier. (1998). *Environmental Science Dictionary*. Collins. (ISBN: 0 04343 448 4; Approx. price: AUD35.00)

Mackean, D G. (1998) *Life Study (A text book of Biology)*. John Murray. (ISBN: 0 7195 3783 5; Approx. AUD35.00).

Mayr E., Diamond J. & Pratt H.D. (Illustrator). (2001). *The Birds of Northern Melanesia: Speciation, Ecology, & Biogeography*. Oxford University Press. (ISBN: 0195141709 Price approx: AUD80.00)

Stanford Environmental Law Society. (2001). *The Endangered Species Act*. Stanford University Press. (ISBN: 0804738432; Price approx. AUD20.00)

Woolley, M. (1998). *Plants and flowers*. Macmillan. (ISBN: 0732950562; Approx. price: AUD30.00)

Weather and climate

Anderton, J (Ed.). (1990). *Fundamental Science for Melanesia Book 3*. Longman: Melbourne.

Aung, T. Kaluwin C & Lennon, G (1998). *Climate Change & Sea Level, Part 1* National Tidal Facility,

Aung, T. Kaluwin C & Lennon, G (1998). *Climate Change & Sea Level, Part 2* National Tidal Facility,

Lutgens, F.K. et al. (2000). *Atmosphere: The: An Introduction to Meteorology* *****
Prentice Hall: NY. Price: Approx. AUD90.00. Excellent resource for the lecturer.

Moran, J.M. and Morgan, M.D. (1991). *Meteorology: The Atmosphere and The Science of Weather*. Macmillan: New York.

Wyndham, H, Messel H & N S W department of Education (1992). *Science for High School Students, Volume 1*.

Web Sites

Bureau of Meteorology (Australia) Site: Lot of good fact sheets about weather available copyright free if source is acknowledged. <http://www.bom.gov.au?>

Weather site – all sorts of goodies for teachers: <ftp://explorer.arc.nasa.gov/pub/Weather/>

Tidal predictions for PNG tidal stations (POM and Lombrum):
http://www.ntf.flinders.edu.au/TEXT/PRJS/PACIFIC/CALENDARS/pn/pn_cal.html

Earth Science

Davis, H. (1994). *Earth- Wise: Earth structure, processes and hazards from a Papua New Guinea*, Port Moresby.

Davis, H. (1999). *Tsunami PNG 1998: Extracts from Earth Talk*. University of PNG. UPNG: Port Moresby. (Class set is a good idea). *****

Geological Time (Chart). Atlantic Europe. ISBN: 1862140634; Approx. price: AUD30.00).

Minerals (chart). Atlantic Europe. (ISBN: 1862140332; Approx. price: AUD30.00

Rosen, S. (1998). *Teachers Manual for Earth Science*. Macmillan. ISBN: 155675 713 1; Approx. price: AUD15.00).

Tarbuck, E. J., Lutgens, F.K. (2000). *Earth Science* 9th Edn (With CD-ROM). Prentice Hall: NY. Price: Approx. \$140.00. Excellent resource for the lecturer.

Web Sites

Orogen Minerals Limited. Leader in the development of natural resources in PNG's mining and petroleum industries: Web Site: <http://www.rogen.com>

Science Hobbyist Site: Full of great experiments and science facts:
<http://www.eskimo.com/~billb/>

Tsunami Information Centre: <http://205.156.54.206/pr/hq/itic.htm>

Stuff for Teachers (Earthquakes): <http://earthquake.usgs.gov/4kids/4teachers.html>

Volcanoes of the World site (includes all PNG volcanoes)
<http://vulcan.wr.usgs.gov/Volcanoes/framework.html>

Earthquake bulletins (gives position of all earthquakes Worldwide soon after the event!)
<http://wwwneic.cr.usgs.gov/neis/bulletin/bulletin.html>

Astronomy

Seeds, M.A. (2000). *Foundations of Astronomy* 6th Edn. (with The Sky CD-ROM, Non-InfoTrac Version). Brookes/Cole: NY.
ISBN 0-534-37860-9 Price: approx. \$140.00. Excellent resource for the lecturer.

Wyatt, P. (1999). *Astronomy for the Southern Hemisphere*. Cambridge. ISBN: 0 521 43999 X; Approx price: AUD20.00).

Web Sites

Lane, D.J. (1997). *The Earth Centered Universe*. Shareware Version 3.0A (**Excellent program for generating star charts for your local area. Shareware version available from website.**)

Nova Astronomics. PO Box 31013, Halifax, Nova Scotia, B3K 5T9
CANADA. **Internet E-Mail:** ecu@fox.nstn.ca
Website: <http://fox.nstn.ca/~ecu/ecu.html>

..

International Space Station Site – gives real times and predictions so that you can watch the station go over! <http://liftoff.msfc.nasa.gov/temp/StationLoc.html>

Graphical predictions and representation of all major satellites (real Time):
<http://liftoff.msfc.nasa.gov/realtime/JTrack/Spacecraft.html>

Sky and Telescope site: Keeps you up to date with astronomical events and is also great
photos on this site: <http://www.skypub.com/sights/meteors/observe.html>

Other general interest science Web sites:

<http://www.nsplus.com/> - Additional content for New Scientist readers

<http://www.last-word.com/> - The Last Word archive of over 350 intriguing science Q & A

<http://www.keysites.com/> - A new expanded top sites and discussion section

<http://www.grand-tours.com/> - Our science travel section

Equipment and consumables

- Jar, Specimen, Plastic, Clear, Stackable, 65mm D x 80mm deep, with screw on lid (need plenty of these for collecting specimens in the field)
- Microscope cover slips 18 x 18 mm, (Box/100)
- Microscope, Hand-Held, Self-illuminating, 30X. (Good cheap alternative to expensive microscopes – good for field work). (Approx. AUD10.00)
- Microscope, stereoscopic, binocular 10X, 30X (one is sufficient) (Approx. AUD350)
- Magnifying lenses 10X
- Deluxe Weather Station (~ AUD170.00)
- Wind Speed Gauge, 110 kilometres/hour
- Rain gauge, plastic, measure 150 mm
- Mineral Kits (AUD18.00)
- Ore kits (~AUD27.00)
- Rock kits (~AUD17.00)
- Geology maps and reports (available from Department of Mines and Energy, PNG)
- Binoculars, Standard Focus, With Case, 10X Magnification, 50° Objective Dia (About AUD75.00)
- Telescope, Polaris 114EQ-D, Reflecting (Available from Camera House Stores, Australia for approx. AUD600); **OR**
- Telescope, Meade DS-60, Refracting (Available from Camera House Stores, Australia for approx. AUD350); **OR**
- Telescope, Meade DS-70EC, Refracting with electronic controls (Available from Camera House Stores, Australia for approx. AUD700).

E1 Ecology

Rationale

The module ecology covers topics in the lower and upper primary syllabuses and therefore is seen as one of the important foundation modules in **Environment Science**.

This module enables students to investigate issues affecting the environment from the broadest scale down to the ecological niche of organisms in terms of the factors that contribute to their distribution and adaptations. The impact of people on their environment is looked at in terms of suitable ways to solve problems.

Ecology is covered extensively and is not seen as new module. As a result most of the work done will be mainly through library research, field research and class presentation so that student teachers grasp the concepts in a meaningful way.

It is also important that student teachers are exposed to some of these issues so that they can help children make better judgements on the types of development they want in their villages and PNG.

This module also aims to prepare students for teaching ecology concepts in the primary curriculum. This module will involve students in practical and field exercises to enhance their knowledge of the local context of earth science. Relevant content from the Primary science curriculum will be applied in the teaching and learning of this module.

Objectives

At the end of this module students should be able to:

Skills

- Observe the environment
- Measure temperature, humidity, pH, wind speed and wind direction,
- Identify types of biogeographical regions, biomes, zones and habitats
- Present research confidently to the class.
- Discuss PNG or global environmental issues
- Draw sketches
- Compare organisms in the same biomes by identifying common features
- Evaluate critically presentations

Knowledge

- State that the climatic, physiographic, edaphic and the biotic factors have a great impact on the distribution and adaptations of organisms.
- Explain and give examples of climatic, physiological, edaphic and biotic factors
- State that ecology is of the interaction that exists between living organisms themselves and the living organism with their environment.
- Discuss and present findings on people's impact on the environment and what precautions to take.
- Analysis or synthesis existing environmental issues and discuss how that would affect them.
- Understand the purpose of research.

Attitude

- Respect each other's views
- Work in perseverance
- Work in small groups

Content and sequencing**1. Distribution and adaptations of organisms**

- Biosphere and biogeographical zones
- Biomes and zones
- Habitats and environment
- Ecological niche
- Abiotic factors - climatic factors; physiographic factors
- Edaphic factors
- Biotic factors

2. Community ecology

- Food chains and food webs
- Ecosystem
- Energy flow and energetics
- Saprophytic nutrition; parasitic nutrition
- Nutrient cycles - carbon, oxygen, nitrogen.

3. Sustainable biological development

- Ecological succession
- Destruction of natural environment and habitats
- Biological development in natural environments

Main ideas developed**Ecosystems**

Ecosystems are complex communities where many different species of plants and animals coexist and are interdependent.

Food and energy flows in ecosystems are complex and easily disturbed by interference, especially by humans.

Animals and plants show adaptations to the particular environment in which they live.

Populations have natural limits determined by habitat and food.

Careful study and research are needed before and during any disturbance to an ecosystem to minimise disruption.

There is a strong link between habitat preservation and species survival.

Sustainable development

Because ecosystems are complex, destruction of even a part of the system can have many unintended consequences.

Careful study and research of ecosystems and habitats should be undertaken before any major project is commenced.

All activities affect the environment. Sustainable activities are preferable to unsustainable development for the preservation of human lifestyles.

Activities such as logging have short term and long term economic and social advantages and disadvantages.

Increases in human population put pressure on the environment.

Teaching and learning approaches

This module will be delivered through the use of support materials, a lecture program, laboratory and field based activities and a workshop/tutorial program. The practical component is strongly based on the application of ecological principles and problem-solving to Papua New Guinea examples. Excursions or field studies are an integral part of the teaching program. Activities provide a hands-on approach to the teaching of this module. Teaching and learning in this module is based on the constructivist model of learning to ensure students have a thorough grounding and understanding of the concepts.

Throughout the teaching of this module there should be a strong emphasis on the constructivist approach to learning that can be readily applied to science teaching in the classroom. Students will be encouraged to apply their new knowledge and skills to the context of teaching at different levels in primary schools.

Suggested teaching strategies

Distribution and adaptations of organisms

Introduce the topic and module by discussing the importance of some PNG organisms such as those on the coins, cuscus, cassowary, pukpuks and bird of paradise. Discuss cultural significance and uses of PNG animals and plants.

Draw a diagram of a globe and use it to show the different biomes excluding actual continent names. (Refer to map on page 2 of student resource).

Prepare or obtain a chart to show different animals found in the different habitats in PNG. For each animal give the common, local and scientific name. This could form the basis of student projects in *Flora and fauna of PNG*.

Community ecology

It is best to introduce this topic through a study of the local area (see suggested student activities, No. 1).

Review concepts of energy from the sun and the importance for photosynthesis in plants. See module P2 and 5, *Energy and Waves* as well. The lecturer could explain how the hawk or crocodile gets its energy from the Sun. Students could try to put in the missing "links" of the food chain or web. Modelling of complete food webs is important to ensure students understand the concepts. Prepare examples of food webs beforehand.

While investigating food chains mention should be made of the affects of chemicals on the food chains. For example, how some pesticides affect bees and therefore honey production.

There are number of issues that are of concern in PNG. Some of these could be a focus for student discussion about food chains and webs. For example, the effect on a food web when netting small fish in a seagrass area, free-felling a forest area or clearing forest for agriculture; the effect of monoculture; the “harvesting” of bird of paradise feathers.

Sustainable biological development

This topic should be taught with reference to similar topics in Social Science and Natural Resources modules.

Reinforce the links between sun, energy, photosynthesis, producers, herbivores and carnivores so students realise the importance of each organism in food chains.

This topic is best introduced through discussion about the effect of human activities on flora and fauna and the food chains. Students will know examples from their own communities. Students could present their findings from discussions.

Introduce the students to the idea of having National Parks and Reserves to preserve ecosystems and endangered species in PNG. Collect information about the PNG parks from the Department of Conservation and Wildlife.

Wherever possible field trips should be used as a strategy to give students first-hand experience in sustainable development, e.g., a replanting program in a logging area, fish farming, etc.

Strategies used in this module could include:

Strategy	Examples
Group work	Produce charts of different food webs in PNG; illustrate the food web; present to class
Debating	Effects of disturbing the food chain – cutting grass, spraying chemicals, digging the soil; cutting trees; clearing for gardening.
Research	Assist and guide students with research rather than just say, “Research this!”
Concept mapping	Relate one food chain to another to make a food web; Use jumbled names of animals, plants and habitats for students to assemble or map food webs.

Suggested student activities

Community ecology

These suggested activities should be integrated with the Module E2, *Flora and Fauna of PNG*. This will ensure that students approach the study of ecology in a holistic way rather than piecemeal. It will also ease the workload for both lecturer and students in the areas of assessment. Some suggested assessment programs are outlined in the separate assessment guidelines for Science.

1. Local study

- (a) Make a map/plan of a small area of bush/garden/forest/reef nearby.
- (b) Try to identify each different species of plant that occurs there (use common names).
- (c) Make a list of all the animals you find or that you would expect to find in that area.
- (d) Use a graph to show the number of individuals of each species in your map area.
- (e) Construct a simple food chain or food web for the area you chose.

2. Terrarium

Construct a terrarium (a closed ecosystem) using empty 2 litre plastic soft drink bottles or similar containers.

- (a) Firstly, research ecosystems and terrariums, then
- (b) plan and design your system and its components.
- (c) Show your plan to the lecturer for discussion and approval.
- (d) Now construct your terrarium.
- (e) Monitor the terrarium over a number of weeks, making notes of all changes.
- (f) Prepare a report on what you have discovered.

3. Food chains and webs

Draw pictures of plants or animals on cards (or cut out pictures from magazines), and make arrows from card to card. Get a partner or your group to rearrange the pictures and arrows into a food chain or food web. Discuss with your group the pattern they have made.

4. Plant collection

Make a collection of pressed leaves from a variety of plants adding local names and scientific names where possible. Pressings can be made by placing the leaves between sheets of newspaper and placing rocks to a board on top. Replace the newspaper regularly. This activity could be extended into E2, *Flora and Fauna of PNG*.

5. Camouflage

Research camouflage in animals. Cut moth shapes from white paper and from newspaper. Place the shapes over newspaper and white paper. Explain to your partner how camouflage works.

Sustainable development

1. Organise the students in your group to collect or draw pictures of animals and their young that are threatened. Cut out the shapes and hang them with string from the classroom ceiling (i.e., make a mobile). Make labels and information boxes to hang with the pictures.
2. Visit the market in your local area and list all the animals (including birds and fish), animal meat or animal products (e.g., eggs, feathers) that are being sold. Sort these into indigenous or introduced animals. Try to determine whether the indigenous animals are or are likely to become endangered.
3. Interview a market seller of animals and determine how much he or she makes from selling that species, what other sources of income he or she has and whether he or she can foresee what would happen if the animal became extinct in the area.
4. Organise a debate between groups of students on a topic such as "Should we take turtle eggs and kill turtles".
5. Find out how species of birds, reptiles and mammals are protected in PNG and who is responsible for policing the laws. Invite a knowledgeable guest speaker to talk to your class on protecting and sustaining native species.
6. Research the life cycle of a species that is or is likely to become endangered. Suggest conservation measures that could be undertaken to preserve the species. Explain why some conservation measures are difficult to put into practice.

E2 Flora and fauna of PNG

Rationale

This module aims to prepare students to teach concepts and ideas related to Papua New Guinea plants and animals in the new primary school curriculum and to encourage effective decision-making in relation to plants and animals in their local environment.

Study of fauna and flora provides a clear understanding of the nature of plants and animals, relationship and differences between plants and animals and other smaller groups. Clear understanding of the plants and animals will enable the students appreciate them, look after them and exploit them with care and consideration.

This module should involve students in practical and field exercises to enhance their knowledge of the local context and culture.

Objectives

At the end of this module the students should be able to:

- list and describe the characteristics of living things;
- describe and name some plants and animals of PNG;
- classify some the plants and animals of PNG;
- conduct research on one species of plant and one species of animal in PNG;
- describe some endangered species of PNG and recognise ways to
- collect data in the field;
- compile a report on the species that have been researched and investigated in the field.

Main ideas developed

Flora and fauna of the local area

The flora and fauna of the local area (and of all of PNG) are precious resources that must be understood, respected and protected by all citizens.

Endangered species in PNG

A number of PNG's flora and fauna are under threat because of habitat removal. It is important that people in PNG are aware of the threats to endangered species.

There is a strong link between habitat preservation and species survival. Conservation of habitats and species is important for the survival of humans.

Factors contributing to the survival of species include competition, habitat, disease, food supply, adaptability, etc.

Careful study and research are needed before any new plants or animals are introduced to the country.

Content and sequencing

Characteristics of living organisms

- Differences between plants and animals

Flora of PNG

- Using keys for classification of plants (flora)
- Forests of PNG

Fauna of PNG

- Classification of animals (fauna)
- Using keys to classify animals (fauna)

Endangered species

- Definitions of endangered and extinct
- PNG examples of endangered species

Project

- Suggested activities/investigation/project
- Project guidelines
- Examples of projects

Suggested teaching strategies

This Topic should be conducted as a Project equivalent to a total of 9 hours of class time, having a focus on the local environment and designed and conducted by individual students or pairs of students. **The Module should not be taught as another lot of content!**

It is important that students are given some training in the skills needed to collect, describe and classify plants and animals in the field. Students may also need some background readings about PNG rainforests and endangered species. Some examples of suitable readings have been given below. The lecturer may decide to share these with the students or provide other suitable readings in the library.

It is good idea to copy at least 5 of any good reading, staple into a manila folder and have the librarian store these on a restricted loan basis, i.e., students must read the resource in the library.

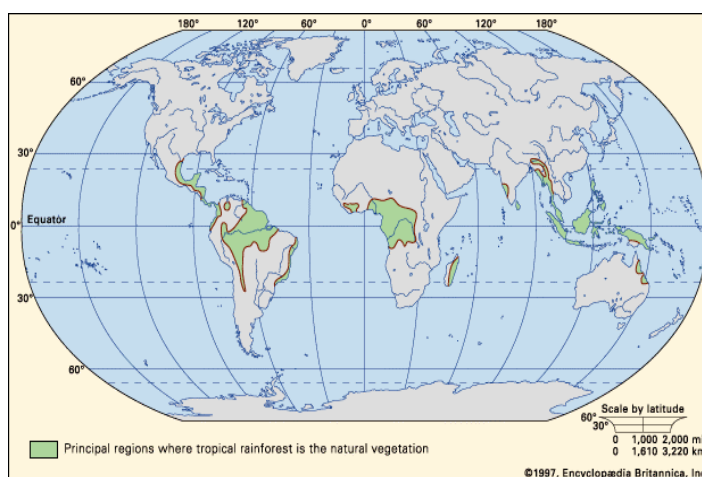
The following readings are exemplars that may assist the Lecturer in directing students with their research.

Tropical rainforests

(from *Encyclopaedia Britannica*,
2001 CD ROM)

Tropical rainforests represent the oldest major vegetation type still present on the terrestrial Earth. Like all vegetation, however, that of the rainforest continues to evolve and change, so that modern tropical rainforests are not identical with rainforests of the geologic past.

Worldwide distribution of tropical rainforests.



Tropical rainforests grow mainly in three regions: the Malesian botanical subkingdom, which extends from Myanmar (Burma) to Fiji and includes the whole of Thailand, Malaysia, Indonesia, the Philippines, **Papua New Guinea**, the Solomon Islands, and Vanuatu and parts of Indochina and tropical Australia; tropical South and Central America, especially the Amazon basin; and West and Central Africa. Smaller areas of tropical rainforest occur elsewhere in the tropics wherever climate is suitable. The principal areas of tropical deciduous forest are in India, the Myanmar-Vietnam-southern coastal China region, and eastern Brazil, with smaller areas in South and Central America north of the Equator, the West Indies, southeastern Africa, and northern Australia.

The flowering plants (angiosperms) first evolved and diversified during the Cretaceous Period about 100 million years ago, during which time global climatic conditions were warmer and wetter than those of the present. The vegetation types that evolved were the first tropical rainforests, which blanketed most of the Earth's land surfaces at that time. Only later, during the middle of the Cenozoic Era, about 40 million years ago, did cooler, drier climates develop, leading to the development across large areas of other vegetation types.

It is no surprise, therefore, to find the greatest diversity of flowering plants today in the tropical rainforests where they first evolved. Of particular interest is the fact that the majority of flowering plants displaying the most primitive characteristics are found in rainforests (especially tropical rainforests) in parts of the Southern Hemisphere, particularly South America, northern Australia and adjacent regions of Southeast Asia, and some larger South Pacific Islands (such as PNG).

Of the 13 angiosperm families generally recognised as the most primitive, all but two, (Magnoliaceae and Winteraceae) are overwhelmingly tropical in their present distribution. Three families, Illiciaceae, Magnoliaceae, and Schisandraceae, are found predominantly in Northern Hemisphere rainforests. Five families, Amborellaceae, Austrobaileyaceae, Degeneriaceae, Eupomatiaceae, and Himantandraceae, are restricted to rainforests in the tropical Australasian region. Members of the Winteraceae are shared between this latter region and South America, those of the Lactoridaceae grow only on the southeast Pacific islands of Juan Fernández, members of the Canellaceae are shared between South America and Africa, and two families, Annonaceae and Myristicaceae, generally occur in tropical regions.

This has led some authorities to suggest that the original cradle of angiosperm evolution might lie in Gondwanaland, a supercontinent of the Southern Hemisphere thought to have existed in the Mesozoic Era (245 to 66.4 million years ago) that consisted of Africa, South America, Australia, peninsular India and Antarctica. An alternative explanation for this geographic pattern is that in the Southern Hemisphere, especially on islands, there are more refugia, *i.e.*, isolated areas whose climates remained unaltered while those of the surrounding areas changed, enabling archaic life-forms to persist.

The first angiosperms are thought to have been massive, woody plants, appropriate for a rainforest habitat. Most of the smaller, more delicate plants that are so widespread in the world today evolved later, ultimately from tropical rainforest ancestors. While it is possible that even earlier forms existed that await discovery, the oldest angiosperm fossils (leaves, wood, fruits, and flowers derived from trees) support the view that the earliest angiosperms were rainforest trees. Further evidence comes from the growth forms of the most primitive

surviving angiosperms: all 13 of the most primitive angiosperm families consist of woody plants, most of which are large trees.

As the world climate cooled in the middle of the Cenozoic, it also became drier. This is because cooler temperatures led to a reduction in the rate of evaporation of water from, in particular, the surface of the oceans, which led in turn to less cloud formation and less precipitation. The entire hydrologic cycle slowed and tropical rainforests, which depend on both warmth and consistently high rainfall, became increasingly restricted to equatorial latitudes. Within those regions rainforests were limited further to coastal and hilly areas where abundant rain still fell at all seasons. In the middle latitudes of both hemispheres, belts of atmospheric high pressure developed. Within these belts, especially in continental interiors, deserts formed. In regions lying between the wet tropics and the deserts, climatic zones developed in which rainfall adequate for luxuriant plant growth was experienced for only a part of the year. In these areas **new** plant forms evolved from tropical rainforest ancestors to cope with seasonally dry weather, forming tropical deciduous forests. In the drier and more fire-prone places, savannas and tropical grasslands developed.

Retreat of the rainforests was particularly rapid during the late Cenozoic (5 million years ago to the present), which is the period leading up to and including the Pleistocene Ice Ages, or glacial intervals, that occurred between 1,600,000 and 10,000 years ago. Climates fluctuated throughout this time, forcing vegetation in all parts of the world to repeatedly migrate, by seed dispersal, to reach areas of suitable climate. Not all plants were able to do this equally well because some had less effective means of seed dispersal than others. Many extinctions resulted. During the most extreme periods (the glacial maxima, when climates were at their coldest and, in most places, also driest), the range of tropical rainforests shrank to its smallest extent, becoming restricted to relatively small refugia.

Alternating intervals of climatic amelioration led to repeated range expansion, most recently from the close of the last glacial period about 10,000 years ago. Today large areas of tropical rainforest, such as Amazonia, have developed as a result of this relatively recent expansion. Within them it is possible to recognize "hot spots" of plant and animal diversity that have been interpreted as glacial refugia.

Tropical rainforests today represent a treasure trove of biological heritage. They not only retain many primitive plant and animal species, they also are communities that exhibit unparalleled biodiversity and a great variety of ecological interactions. The tropical rainforest of Africa was the habitat in which the ancestors of humans evolved, and it is where the nearest surviving human relatives (chimpanzees and gorillas) live still.

Tropical rainforests supplied a rich variety of food and other resources to indigenous peoples, who, for the most part, exploited this bounty without degrading the vegetation or reducing its range to any significant degree. However, in some regions a long history of forest burning by the inhabitants is thought to have caused extensive replacement of tropical rainforest and tropical deciduous forest with savanna.

Not until the past century, however, has widespread destruction of tropical forests occurred. Regrettably, tropical rainforests and tropical deciduous forests are now being destroyed at a rapid rate in order to provide resources such as timber and to create land that can be used for other purposes, such as cattle grazing. Today, tropical forests, more than any other ecosystem, are experiencing habitat alteration and species extinction on a greater scale and at a more rapid pace than at any time in their history--at least since the major extinction event at the end of the Cretaceous Period some 66.4 million years ago.

Managing natural communities

(from Encyclopaedia Britannica, 2001 CD ROM)

The idea that biologic communities should be protected for their own intrinsic value is of relatively recent origin. Although natural communities have been protected since ancient times, the reasons for doing so have not been related to the value of the community per se but to some special feature that was of value to people. Thus, hunting preserves were protected in ancient Mesopotamia, in China, and in England, where the New Forest was set aside by William the Conqueror. While such preserves protected natural areas, their major purpose was to provide a setting for royal hunting. Temple gardens have been preserved over the centuries in China and Japan; the cedars of Lebanon were maintained around holy places. But, again, such preservation was fortuitous rather than intentional.

The idea of preserving wild areas for their own value had its origin in the United States with Catlin, Thoreau, Muir, and others of similar mind. Only more slowly has this concept been accepted in other countries. Appreciation of wild nature is acquired along with scientific knowledge, particularly ecological knowledge. It is a sophisticated taste not usually to be found among those who earn their livelihood in close contact with the wild. Nevertheless, the concept of preserving wild nature for its own value has become widely accepted, although the means for implementing it are not necessarily available in every country.

Natural communities, little affected by human activities, are thought to be worth preserving for a variety of reasons. First, perhaps, is the scientific benefit to be derived from studying them, particularly concerning the functioning of the biosphere. From studies of undisturbed ecosystems much can be learned about the behaviour of those systems modified for the production of useful materials. Also, the value of wild species has been little explored; in their totality they are known to be essential to the function of the biosphere, but the importance of individual species is little understood.

Past experience has demonstrated that wild species of little apparent value may prove to be of major importance to medical research and human health. Sea urchins, for example, are used in studies of embryology; non-human primates (*e.g.*, monkeys and apes) are used for many studies of human functions and diseases; armadillos are used to study leprosy; and a great variety of wild plants are used as sources of drugs and medicines. Much of the knowledge of population growth and social behaviour under various conditions of crowding has come from the study of wild mammals.

Furthermore, it is known that more or less undisturbed natural communities are important to the continued operation of those systems that people have created. Watershed forests are protected so as to maintain stream flow and to avoid siltation of reservoirs; estuaries are protected so as to guarantee the continued production of forms of marine life important for food or other purposes. Finally, there are aesthetic and recreational values attached to wild areas and wildlife. It would appear that outdoor activities in a natural setting or contact with plants and animals in a wild state are important to psychological well-being, because people of all races and cultures seek such experiences when they achieve the affluence that enables them to do so.

Biologic communities can be protected in a variety of ways, depending upon the desired objectives. The most difficult and exacting task is the protection of unmodified natural communities, with their full array of wild species, for use in scientific research. Because such communities are becoming increasingly rare, the major efforts to protect them are

undertaken at an international level, as well as at the national level. The International Biological Program, a Worldwide research effort, has focused attention on the many kinds of natural communities that require protection. The International Union for Conservation of Nature and Natural Resources, a semi-governmental international agency, devotes an important part of its activities to the establishment of reserves and parks for the protection of natural communities. The United Nations, through its Food and Agricultural Organisation (FAO), UNEP, and UNESCO, has contributed to the establishment of many parks and reserves in developing nations. Yet, despite such activities, certain kinds of natural communities will be irrevocably lost unless there is greater effort toward their conservation.

The danger to natural communities and wild species comes from many causes. One long-standing problem derives from the exploitation of wild species that have commercial value, as, for example, the widespread removal of mahogany trees and other valuable timber from the forests around the Caribbean area. The uncontrolled hunting of whales and other sea mammals has brought some species to the point of near-extinction, and at least one, Steller's sea cow (like the PNG Dugong!), has been exterminated. The demand for such high-fashion products as shoes and handbags made from crocodile skins or coats and wraps made from the skins of tigers and leopards has endangered the continuing existence of these animals.

Control of those species considered to be detrimental has led to an unreasonable warfare against predatory animals. As a result, the wolf, cougar, lion, lynx, eagles and hawks of various species, and other carnivorous animals have been eliminated from the vicinity of human settlements or from pastoral lands, even though the evidence that some of these species do any appreciable damage is not well substantiated. But the greatest single cause for the depletion of natural communities and wild species has been the desire to use land for more productive purposes. This has led to extensive clearing of forests and woodlands, burning of vegetation, and the cultivation of previously undisturbed land for crop production. Many of the lands that are cleared eventually prove to be poorly suited for the purposes for which they are intended and are ultimately abandoned; however, it is then no longer possible to protect the natural communities that previously existed in these areas.

Programs for the protection of natural communities must involve, first, rational planning for the use of land and control over its exploitation by agencies charged with such responsibilities. Adaptation of land use for commodity production by using only those sites best suited for such purposes is a first step toward protecting other lands that are now being cleared unwisely. Although the establishment and proper management of parks and reserves permits the survival of certain species in certain areas, a more general program of rational management and use of all lands and species is essential to the long-term survival of wild nature throughout the world.

Concepts important to conservation

(from Encyclopaedia Britannica, 2001 CD ROM)

The need for natural resources

Like "conservation" itself, the term natural resources has undergone an expansion in meaning as a result of a greater understanding of the relationship of human beings with the world they inhabit. Early in the 20th century natural resources were viewed primarily as sources of useful commodities. They were the raw materials in the environment that were used or

capable of being used by people for some purpose: minerals and fuels, forest and grazing resources, wildlife, fisheries, and the like. In a restricted sense, the term is still used in this way. More recently, however, the concept of natural resources has been broadened to include the total natural environment--the entire surface layer of the planet--because all parts of the Earth's surface are of use and of value in that they contribute to the production of the necessities and amenities that people require or demand. Thus, when considered in this respect, the atmosphere, oceans, deserts, and polar regions have all become valuable resources that must be managed with care to provide for the future.

Techniques for wildlife conservation

Wildlife-conservation techniques have counterparts in forestry and in soil, water, and landscape conservation. They include prohibitions, and controls, restoration, subsidy, sanctuary, and public ownership.

The oldest forms of prohibitions and controls are those that regulate hunting, fishing, and trapping. Although, as already stated, many early regulations resulted in misguided efforts aimed solely at increasing game populations, other early controls did play an important role in protecting wildlife. Especially useful were those limitations on hunting that protected animals during the breeding season. Bag limits, *i.e.*, limits on the number of animals that can be taken by an individual hunter, fisher, or trapper--are also important conservation tools. Although modern limitations on hunting, fishing, and trapping have successfully adjusted available game supplies to mounting human populations in much of North America and Western Europe, they have been less successful in countries where the rural population is poverty-stricken and poorly fed. Moreover, the exploitation of migratory waterfowl has been successfully regulated only in North America, where, because few countries are involved, international treaties are easier to work out than they are elsewhere.

Among the most important modern legal tools in wildlife conservation are those laws that protect threatened and **endangered** species. In the United States, for example, the **Endangered** Species Act makes it illegal to hunt, trap, or collect **endangered** animals and plants. The act also tightly restricts the use of federal funds in projects that are likely to adversely affect **endangered** species, and it prohibits the importation of **endangered** species or products made from **endangered** species.

Perhaps equally important are those laws that mandate pollution controls; the resultant improvements in air and water quality enhance the prospects for wildlife (not to mention human) survival. The amelioration of habitats that have been damaged by pollutants is often a lengthy process, however, and in many cases the implementation of anti-pollution laws has been hampered by litigation and by lax enforcement.

Artificial methods of offsetting resource depletion include programs of population restocking and habitat restoration. Game farms and fish hatcheries, which provide stocks of popular game species, are long-established tools of wildlife management. Of more recent development are those programs designed to restock wild populations of **endangered** species with individuals raised in captivity. Captive rearing and release is part of the effort being made to save the **endangered** whooping crane of North America. A similar program has been undertaken in behalf of the California condor, another **endangered** North American bird. Such efforts depend not only on the successful rearing of the **endangered** species in captivity but also on the ability of the released individuals to make the transition to

life in the wild. An even more ambitious approach is the restoration of degraded habitats. Habitat restoration has frequently

proved to be expensive, but its results are dramatic in the restoration of marshes, as is now evidenced in many of the national wildlife refuges in the United States.

The oldest types of subsidies are bounties on predators and crop-destroying species, which were offered at least as early as the Middle Ages in England. Some surviving bounties are deplored by ecologists but sponsored by politicians as a form of unofficial rural relief. In the United States, federal subsidies are intended to encourage municipalities to construct sewage works and farmers to retire land in the soil-bank program.

Sanctuaries, also called preserves, reserves, and refuges, have been prominent in wildlife conservation since the mid-19th century. With the large national parks, they have provided the protection and space critically needed in America and Africa by the larger predators and grassland-dwelling big game and the freedom from human interference needed by nesting birds during the breeding season; in the United States they also give migratory waterfowl at least partial relief from hunting pressure. In the United States, public ownership, which usually accompanies the establishment of sanctuaries, facilitates the management of wildlife food and cover resources to an extent seldom possible on privately owned lands.

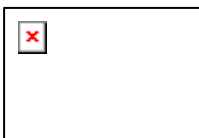
Public ownership finds its soundest manifestations in the development of sanctuaries and in the preservation of wildlife in national parks, though government ownership of forests in Canada and the United States also helps maintain various species of wildlife.

Functions and values of wetlands

Wetland functions are physical, chemical, and biological processes or attributes that are vital to the integrity of the wetland system. Because wetlands are often transition zones (ecotones) between uplands and deepwater aquatic systems, many processes that take place in them have a global impact: they can affect the export of organic materials or serve as a sink for inorganic nutrients. This intermediary position is also responsible for the biodiversity often encountered in these regions, as wetlands "borrow" species from nearby aquatic and terrestrial systems. Wetlands play a major role in the biosphere by providing habitats for a great abundance and richness of floral and faunal species; they are also the last havens for many rare and **endangered** species. Some wetlands are considered among the Earth's most productive ecosystems. The wetland's function as a site of biodiversity is also valuable to humans, who rely on these ecosystems for commercial and sport fishing, hunting, and recreational uses. The capacity of wetlands to absorb a great amount of water also benefits developed areas. A wetland system can protect shorelines, cleanse polluted waters, prevent floods, and recharge groundwater aquifers, earning wetlands the sobriquet "the kidneys of the landscape."

Some endangered species

Humpback whale



Humpback whale (*Megaptera novaeangliae*) breaching (*Megaptera novaeangliae*, or *M. nodosa*), baleen whale, the only species of the genus *Megaptera*, belonging to the family Balaenopteridae. The humpback is a thickset whale that usually attains a length of about 12 to

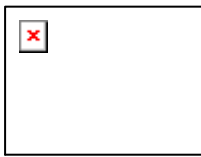
16 m (40 to 52 feet). It is black, with a variable amount of white below, and is distinguished by its very long, narrow pectoral fins--scalloped on the forward edge--and by large knobs, each associated with one or two hairs, on its head and jaws. The dorsal fin is small and set far back, and there are about 20 length-wise grooves on the throat and chest.

The humpback lives along the coasts of all major oceans, occasionally swimming close inshore or even into harbours and up rivers. It migrates between polar oceanic waters in summer and tropical or subtropical breeding grounds in winter. Its diet consists of shrimp like crustaceans, small fish, and plankton, which it strains out of the water by means of its baleen. The humpback is one of the most acrobatic of all whales. On occasion it may perform a somersault by leaping from the water belly up, arching backwards, and plunging headfirst back into the water with a loud slapping sound. When making deep dives, it hunches its back and rolls steeply forward, bringing its tail vertically clear of the water.

The humpback is also probably the most vocal of all whales, making a great variety of sounds which it strings together to form a "song" that may last from 5 to 35 minutes. The sounds range from moans and cries, to groans and snores. The songs themselves vary among groups of whales in different areas of the ocean, and the songs undergo gradual but distinctive changes from year to year.

The humpback whale is commercially valuable and was much reduced in numbers by over hunting in the early and mid-20th century. Protected Worldwide since the mid-1960s, it is listed as an **endangered** species in the *Red Data Book*.

Wallaby



Wallaby refers to any of several middle-sized marsupial mammals belonging to the kangaroo family, Macropodidae (kangaroos). They are found chiefly in Australia and PNG. The 11 species of brush wallabies (genus *Macropus*, subgenus *Protemnodon*) are built like the big kangaroos but differ somewhat in dentition. Their head and body length is 45 to 105 cm (18 to 41 inches), and the tail is 33 to 75 cm long. A common species is the red-necked wallaby (*M. rufogriseus*), with reddish nape and shoulders, which inhabits brushlands of southeastern Australia and Tasmania; this species is often seen in zoos. The pretty-faced wallaby, or whiptail (*M. elegans*, or *M. parryi*), with distinctive cheek marks, is found in open woods of coastal eastern Australia.

The six named species of rock wallabies (*Petrogale*) live among rocks, usually near water. They are prettily coloured in shades of brown and grey and are distinguished by stripes, patches, or other markings. They are extremely agile on rocky terrain. The three species of nail-tailed wallabies (*Onychogalea*; see photograph).

photograph: Bridled nail-tailed wallaby (*Onychogalea fraenata*) are named for a horny growth on the tail tip. They are handsomely striped at the shoulder. Because they rotate their forelimbs while hopping, they are often called organ-grinders. Two species are **endangered**

The two species of hare wallabies (*Lagorchestes*) are small animals that have the movements and some of the habits of hares. Often called pademelons, the three species of scrub wallabies (*Thylogale*) of New Guinea, the Bismarck Archipelago, and Tasmania are small and stocky, with short hind limbs and pointy noses. They are hunted for meat and fur.

A similar species is the short-tailed scrub wallaby, or quokka (*Setonix brachyurus*); this species is now restricted to two offshore islands of Western Australia.

Dugong

The dugong (species ***Dugong dugon***) is a large marine mammal of the order Sirenia that is the sole extant member of the family Dugongidae. It inhabits shallow coastal waters from the Red Sea and eastern Africa to the Philippines, New Guinea, and northern Australia.

The **dugong** ranges in length from about 2.2 to 3.4 m (7 to 11 feet) and usually weighs from 230 to 360 kg (500 to 800 pounds). It has a round, tapered body that ends in a flipper with paired, pointed, horizontal branches. The forelimbs are rounded flippers; there are no hind limbs. The head, which blends into the body with no visible neck, has a broad, square, bristled snout. A single calf is born after a gestation period of about 11 months, after which it nurses on its mother's two pectoral (chest) teats.

Dugongs live in pairs or in groups of up to six individuals. They graze on green algae and marine grasses, remaining submerged up to 10 minutes. When resting, they may "tail stand" in water of proper depth, keeping their heads out of the water. Sightings of dugongs by early seafarers are believed to have given rise to the extensive mythology of mermaids and sirens.

Dugongs were heavily hunted for their meat, hides, and oil. Although they are now protected by law throughout most of their range, some populations remain in danger of extermination through over hunting.

Suggested student activities

Endangered species

These activities may be selected to initiate discussion in preparation for students to conduct their own independent research.

1. Organise a class debate on the general theme of endangered species. Set clear rules for the debate. Topics could include "Our Home versus Their Habitat" or "Endangered Species should not be killed".
2. Write definitions in your own words to explain the following concepts: species, threat, endangered, habitat, quarantine, adaptation. Research which animals from PNG are listed as endangered. Design a poster suitable for Grade 4 students that raises awareness of endangered species.
3. Research a threatened species, such as dugong, bird of paradise, green turtle, butterflies, etc. Present a short verbal report of your research to the class.
4. Collect samples of introduced plants that have become pests or weeds in PNG. Discuss with your group the effects of these plants on native vegetation.
5. Write a story suitable for Grade 5 children that tells of the effect of logging on an area and its people. Illustrate your story and make it into a large format book.
6. Draw the life cycle of a PNG butterfly and identify the threats and hazards it faces at each stage of development. Turn your drawing into a wall chart suitable for a Grade 5 classroom.

7. Write a simple story under the heading "What Am I?", so that Grade 4 children have to guess from the description what the animal or plant is.
8. Invite an expert on animals or plants to give a talk to the class on the importance of preventing entry of diseases, newly discovered species, etc. Quarantine officers, conservation officials, rangers, visiting researchers, etc. are good examples.

Examples of Projects include:

1. (a) Collect specimens (make sure that collection contains only the remains of animals, e.g., shells, feathers, dead coral pieces, etc., not live animals!) from a local area of bush/garden/forest/reef nearby. (b) Devise your own classification system for the materials you have collected. (c) Compare your classification system with the scientific system. (d) Prepare a labelled display of your collection for the group. (e) Report to your group the advantages and disadvantages of your system and the scientific system.
2. Investigate the capture, use and sale of fauna or flora from the local area. Produce a display including such things as specimens and charts to highlight the effects of these activities on the fauna or flora. Report to your group on your findings.
3. Study one local species of native plant or animal that is endangered and produce a chart of its life cycle, habitat, food, use, etc. Prepare a display of pictures, drawings, specimens, etc. to explain as much detail as you can about the species. Produce a report of your findings for the group.

4. Animal study

Choose an animal group, e.g., birds/fish/mammals and make a list of as many examples that you can of members of that group that are found in PNG. Use any resource material from books, the library or magazines to add to your list. Make up a chart with:

- (a) the name of each animal,
 - (b) a drawing of it,
 - (c) the type of food you think it eats,
 - (d) its habitat and
 - (e) any adaptation the animal has that helps it to survive in its habitat.
5. Collect specimens of different plants from the local area which are used for specific purposes such as clothing, building, medicines, ornament, eating, ceremonies, magic, etc. Make a display of them including labels with names (local and scientific, if possible), uses, special details, etc. Prepare a report for the group on your findings.
 6. Make a detailed study of an area that has recently been logged. Interview local landowners and communities to determine how decisions were made, what aspects of the process the community is satisfied and dissatisfied with, what advice was sought and obtained, what advantages and disadvantages have come to the community, etc. Take photographs for a display and prepare a report on your findings.

E3 Weather and climate

It is essential that this module on weather and climate be taught before Ecology.

This Module is intended as a **resource only** to support the teaching of the Core Modules, E1, *Ecology* and A5, *Earth Resources*.

Rationale

Many of our activities are directly related to or affected by the weather. Fishermen or fisherwomen need to identify, at a grass roots level, the impending danger from winds at sea, squalls and storms. Villages may also be affected by the consequences of sudden downpours, violent storms and resulting floods. Some basic knowledge of weather is useful in preserving life and property.

Some of the content in this Module, particularly the water cycle, is integrated into the Ecology studies. Weather affects many organisms in the environment, not just humans. Therefore this module should be studied before Ecology or Earth Resources.

Objectives

At the end of this module students should be able to:

- (a) Describe and illustrate the water cycle and relate it to the effects on the environment local village life;
- (b) Describe the water cycle at a molecular level;
- (c) Relate groundwater to the availability of water for wells;
- (d) Describe the main climates of different areas of PNG;
- (e) Measure and record elements of weather such as temperature, humidity and rainfall;
- (f) Relate weather to weather maps and historical records;
- (g) Describe the effects of weather patterns on winds, especially at sea;
- (h) Relate weather forecasts to the conditions at sea;
- (i) Describe ozone chemically and the effects that certain human activities have on the ozone layer;
- (j) Understand that the greenhouse effect is a natural occurrence and that the Earth would not be habitable without it;
- (k) Describe global warming as a consequence of both natural and human activities.

Main ideas developed

Water cycle

All the water used by humans does 'not disappear but continues through a cycle.

Energy from the Sun drives changes of state of water molecules through a cycle that is endlessly repeated.

The oceans form the largest body of water but some water is occurs as groundwater.

When water evaporates, materials such as salt and soil remain behind, only the water molecules change to a gas.

Weather

Weather results from a combination of factors such as temperature, rainfall, etc. at a particular location at a particular time.

The climate at a location is the result of the weather acting over a long period of time.

The weather can be predicted by taking measurements and observing repeated patterns over time.

Meteorologists use a world standard for predicting and reporting weather events;

The sea can be very treacherous due to the forces of winds generated by pressure systems.

Understanding weather patterns and forecasts is essential for day-to-day survival.

Greenhouse affect and global warming

Human activities have an impact on the ozone layer in the atmosphere.

The ozone layer is an important protector of living things on Earth.

An increase in greenhouse gasses is believed to be causing an overall increase in the temperature at the surface of the earth.

Global warming may have a number of potential impacts on human activity.

Content and sequencing

Water cycle

- Cloud types

Weather

- Weather measurement
- Wind
- Global circulation
- Sea conditions

Climate

- Climatic regions and seasons
- Tropical climates

Greenhouse effect and global warming

- Layers of atmosphere
- Greenhouse effect
- Global warming
- Ozone

Suggested teaching strategies

The emphasis in this module should be on the scientific aspects not the emotive issues.

Water cycle

Use a chart showing the water cycle to introduce this topic. Discuss factors affecting the water cycle and how these might affect water supply in PNG.

Ask students to relate their own experiences with water availability and use. Provide students with examples of water needs throughout PNG and the world. It is a good idea to compare the availability of water in cities and towns with that in communities and islands.

How do inhabitants of small sand islands (atolls, etc) get drinking water?

Discuss the problems associated with drought and water wastage in PNG and other parts of the world. (Refer to the drought in the Highlands in 1997.)

Weather

The topic of weather should be introduced using student experiences of weather. Many students who live near the sea may be able to describe boating experiences on the sea and the effects of strong winds. Highland students will be familiar with frost, fog, mist and rainy days.

What forms of weather prediction existed in traditional societies? Illustrate the traditional beliefs on a chart.

All students should be acquainted with modern weather forecasts from radio or television or the newspaper. It is a good idea to use the forecasts from TV or papers to relate the terms given in forecasts. These are universal terms used Worldwide!

Finally students must be involved with the practical measurement and observation and recording of weather at their local area (college). Students could also be involved in improvising weather instruments from basic materials. They could make their own weather vane or wet and dry bulb thermometer. (See suggested student activities).

Students should also be introduced to the modern instruments which record weather – satellite imagery (cloud maps), weather balloons and a host of computerised instruments. (There is a good example of a computerised tidal facility at Lombrum, Manus Islands. This facility sends data to a satellite, which then beams the information to a University in Australia as part of a world network. This research is helping us understand tides and sea level changes and the El Nino.)

Reading for lecturers

The following information has been supplied courtesy of the Australian Bureau of Meteorology Fact sheets and brochures (*Source: Weather Words. Bureau of Meteorology, Australia - 1997*)

Meteorologists, preparing weather forecasts and warnings, compress a lot of information into standardised, brief messages. Their predictions for electronic media and newspaper 'headline' forecasts must be particularly concise. Working under frequent deadlines (all capital city forecasts, for instance, are updated several times a day), forecasters summarise information using consistent terminology to minimise the risk of misunderstanding.

Because forecasts are written for a specific time span and area, they should not carry too much detail, as they must be valid over large areas, perhaps 10 000 square kilometres for a capital city.

The following definitions of some common forecasting terms will help you extract the maximum information from forecasts. In particular note that *fine* means the absence of rain or other precipitation such as hail or snow, not 'good' or 'pleasant' weather.

Cloud talk

- Clear** Free from cloud, fog, mist or dust haze.
- Sunny** Little chance of the sun being obscured by cloud. (Note: High level cirrus clouds are often thin and wispy, allowing a considerable amount of sunlight to penetrate them, sufficient to produce shadows. In this case the day could be termed sunny even though more than half the sky may be covered in cirrus cloud.)
- Cloudy** Predominantly more cloud than clear sky. For example during the day the sun would be obscured by cloud for substantial periods of time.
- Overcast** Sky completely covered with cloud.
- Forecasts of cloud cover normally give an average, if no significant variations are expected. A *clear day*, for example, may at some times see a few cloud patches.
 - Forecasters expecting significant variations in cloud amount may use such terms as *sunny periods*, *sunny breaks*, *cloudy periods*, *cloudy at times*, *mostly/mainly sunny*, *mostly/mainly cloudy*.
 - If expecting a major change in cloud cover, they usually indicate a distinct trend, e.g., *becoming sunny* or *cloud increasing*.

Precipitation talk

Precipitation is any or all of the forms of water particles, whether liquid (e.g., rain, drizzle) or solid (e.g., hail, snow), that falls from a cloud or group of clouds and reach the ground.

Drizzle Fairly uniform precipitation composed exclusively of very small water droplets (less than 0.5 mm in diameter) very close to one another.

Dry Free from rain. Normally used when preceding weather has also been relatively dry, and dry weather is expected to continue for at least a day or so.

Fine No rain or other precipitation (hail, snow, etc). The use of *fine* is generally avoided in excessively cloudy, windy, foggy or dusty conditions.

Fog Suspension of very small water droplets in the air, reducing visibility at ground level to less than a kilometre.

Frost Deposit of soft white ice crystals or frozen dew drops on objects near the ground; formed when surface temperature falls below freezing point.

Mist Similar to fog, but visibility remains more than a kilometre.

Length (How long will it rain?)

- | | |
|---------------------|---|
| Brief | Short duration. |
| Intermittent | Precipitation which ceases at times. |
| Occasional | Precipitation which while not frequent, is recurrent. |
| Frequent | Showers occurring regularly and often. |

Continuous	Precipitation which does not cease, or ceases only briefly.
Periods of rain	Rain is expected to fall most of the time, but there will be breaks.

Intensity

Slight or light

Rain	Individual drops easily identified, puddles form slowly, small streams may flow in gutters.
Drizzle	Can be felt on the face but is not visible. Produces little run off from roads or roofs. Generally visibility is reduced, but not less than 1000 m.
Snow	Small sparse flakes. Visibility generally reduced but not less than 1000 m.
Hail	Sparse hailstones of small size, often mixed with rain

Moderate

Rain	Rapidly forming puddles, down pipes flowing freely, some spray visible over hard surfaces.
Drizzle	Window and road surfaces streaming with moisture. Visibility generally between 400 and 1000 m.
Snow	Large numerous flakes and visibility generally between 400-1000 m.
Hail	Particles numerous enough to whiten the ground.

Heavy

Rain	Falls in sheets, misty spray over hard surfaces, may cause roaring noise on roof.
Drizzle	Visibility reduced to less than 400 m.
Snow	Numerous flakes of all sizes. Visibility generally reduced below 400 m.
Hail	A proportion of the hailstones exceed 6mm diameter.

Distribution of showers (or other weather phenomena)

Few	Indicating timing, not an area.
Isolated	Showers which are well separated in space during a given period.
Local	Restricted to relatively small areas.
Patchy	Occurring irregularly over an area.
Scattered	Irregularly distributed over an area. Showers which, while not widespread, can occur anywhere in an area. Implies a slightly greater incidence than isolated.
Sporadic	Scattered or dispersed in respect of locality or local distribution. Characterised by occasional or isolated occurrence.
Widespread	Occurring extensively throughout an area.

RAIN	Precipitation of liquid water drops greater than 0.5 mm in diameter. In contrast to showers, it is steadier and normally falls from stratiform (layer) cloud.
SHOWERS	Falls of rain, hail or snow which usually begin and end suddenly. Relatively short-lived, but may last half an hour. Often, but not always, separated by blue sky
SMOG	Smog (contraction for 'smoke fog') is a fog in which smoke or other forms of atmospheric pollutant have an important part in causing the fog to thicken, and have unpleasant and dangerous physiological effects.
THUNDERSTORM	One or more sudden electrical discharges manifested by a flash of light (lightning) and a sharp rumbling sound (thunder). A severe thunderstorm produces hail at the ground with a diameter of 2 cm or more; wind gusts at the ground of 90 kph or more; tornadoes; very heavy rain likely to cause flash flooding.
TORNADO	A violent whirl, generally clockwise, averaging about 100 m diameter.

Wind words

The wind is a continuous succession of gusts and lulls associated with equally rapid changes of direction over a range, which may exceed 30°. The mean wind speed over a period of time is therefore the mean of many gusts and lulls. Usually only the mean wind is forecast, unless the gusts are expected to be a significant feature. For instance, Fresh, gusty southwest winds indicates that the mean wind speed will be between 17 and 21 knots and the mean wind direction will be from the southwest, but that there will also be gusts to speeds significantly higher than the mean.

Gust

A gust is any sudden increase of wind of short duration, usually a few seconds.

Squall

A squall comprises a rather sudden increase of the mean wind speed, which lasts for several minutes at least before the mean wind returns to near its previous value. A squall may include many gusts.

Wind Description derived from the Beaufort Scale

	Limits in knots	km/h	Description on land	Description at Sea
Calm			Smoke rises vertically	Sea like a mirror
Light winds	10 knots or less	19 km/h or less	Wind felt on face; leaves rustle; ordinary vanes moved by wind.	Small wavelets, ripples formed but do not break; a glassy appearance maintained.
Moderate winds	11-16 knots	20-30 km/h	Raises dust and loose paper; small branches are moved.	Small waves - becoming longer; fairly frequent white horses.
Fresh winds	17-21 knots	31-39 km/h	Small trees in leaf begin to sway; crested wavelets form on inland water.	Moderate waves, taking a more pronounced long form; many white horses are formed - a chance of some spray
Strong winds	22-27 knots (<i>Strong wind warning issued at 25 knots</i>)	41-50 km/h	Large branches in motion; whistling heard in telephone wires; umbrellas used with difficulty.	Large waves begin to form; the white foam crests are more extensive with probably some spray
	22-33 knots	51-61 km/h	Whole trees in motion; inconvenience felt when walking against wind.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along direction of wind.
Gale	34-40 knots (<i>Gale warning issued at 34 knots</i>)	62-74 km/h	Twigs break off trees; progress generally impeded.	Moderately high waves of greater length; edges of crests begin to break into spin drift; foam is blown in well marked streaks along the direction of the wind.
	41-47 knots	75-87 km/h	Slight structural damage occurs -rooting dislodged; larger branches break off.	High waves; dense streaks of foam; crests of waves begin to topple, tumble and roll over; spray may affect visibility
STORM	48 – 55 knots	88-102 km/h	Seldom experienced inland; trees uprooted; considerable structural damage.	Very high waves with long overhanging crests; the resulting foam in great patches is blown in dense white streaks; the surface of the sea takes on a white appearance; the tumbling of the sea becomes heavy with visibility affected.
	>56 knots	>103 km/h	Very rarely experienced - widespread damage.	Exceptionally high waves; small and medium sized ships occasionally lost from view behind waves; the sea is completely covered with long white patches of foam; the edges of wave crests are blown into froth.

Sea words

- Sea waves** Sea waves are those generated by the wind blowing at the time, and in the recent past, in the area of observation.
- Swell waves** Waves which have traveled into the area of observation after having been generated by previous winds in other areas. These waves may travel thousands of kilometres from their origin before dying away. There may be swell present even if the wind is calm and there are no 'sea' waves.
- Wave period** The average time interval between passages of successive crests (or troughs) of waves.
- Wave height** Generally taken as the height difference between the wave crest and the preceding trough.
- Wave length** The mean horizontal distance between successive crests (or troughs) of a wave pattern.

Sea and swell states

Description	Height (metres)	Effect
Calm (glassy)	0	No waves breaking on beach
Calm (rippled)	0 - 0.1	No waves breaking on beach
Smooth	0.1 - 0.5	Slight waves breaking on beach
Slight	0.5 - 1.25	Waves rock buoys and small craft
Moderate	1.25 - 2.5	Sea becoming furrowed
Rough	2.5 - 4	Sea deeply furrowed
Very rough	4 - 6	Sea much disturbed with rollers having steep fronts
High	6 - 9	Sea much disturbed with rollers having steep fronts (damage to foreshore)
Very high	9 - 14	Towering seas
Phenomenal	over 14	Precipitous seas (experienced only in cyclones)

Swell

Description	Wave Length	Period	Wave Height
Low swell of short or average length	0 – 200	Less than 11 sec	0-2 m
Long, low swell	over 200 m	Greater than 11 sec	0-2 m
Short swell of moderate height	0-100 m	Less than 8 sec	2-4 m
Average swell of moderate height	100-200 m	Greater than 8 sec, less than 11 sec	2-4 m
Long swell of moderate height	over 200 m	Greater than 11 sec	over 4 m
Short heavy swell	0-100 m	Less than 8 sec	2-4 m
Average length heavy swell	100-200 m	Greater than 8 sec, less than 11 sec	over 4 m
Long heavy swell	over 200 m	Greater than 11 sec	over 4 m

Causes of thunderstorms

(From Encyclopaedia Britannica 2001, CD ROM)

Thunderstorms occur when the atmosphere exhibits instability. In essence, when a weather system is unstable, a small displacement leads to a larger one. When the atmosphere is unstable, a volume of air having an upward displacement for any reason will continue moving upward at an accelerating rate. If a sufficiently large mass of air begins rising, an updraft will result. If the air is moist as well as unstable, a cloud will form. Further growth can lead to precipitation and lightning.

The atmosphere becomes unstable when the temperature decreases rapidly with height, this change resulting most often from solar heating of the Earth's surface and of the air in the lowest layers of the atmosphere. Some of the heat is transported upward by means of molecular motion and small-scale turbulent eddies of air. If the incoming energy exceeds that being transported upward, the temperatures in the lowest layers rise, causing the temperature lapse rate (the rate of temperature decrease with height) to increase. When the lapse rate exceeds certain specific values depending on the humidity properties of the air, the atmosphere becomes unstable. If upward air motion is initiated by a mountain ridge, for example, a rising convection current is set in motion. The ascending stream of air will be warmer and more buoyant than the surrounding air. Heat and moisture are carried upward. Counter currents transport cooler and drier air downward. The associated puffy clouds that start as cumulus and may become cumulonimbus are called convective clouds.

Such clouds may be initiated in a variety of ways. Some early studies indicated that convective clouds and thunderstorms were initiated as a result of excessive warming of certain surface areas. The temperature differences were attributed to differences in the colour and hence the absorption properties of various soils and rocks. Sometimes thermals may be traced to such hot spots, but evidence indicates that most thunderstorms are set off as a result of organised lifting of the air.

As noted previously, mountain ridges are important in generating thunderstorms. Not only do the ridges serve as a barrier that forces the air to rise but they also become what are sometimes called high-level heat sources. Solar heating of the high terrain causes the air close to them to be warmer than the air at the same altitudes over the adjacent valleys. Because the warm air is less dense, it rises through the surrounding cooler and heavier air. The importance of this effect is shown by the fact that, even in mountainous areas, most thunderstorms occur during the afternoon and early evening hours when it is warmest.

Thunderstorms are often initiated when a cold front advances toward moist, unstable air (see above), which is forced to rise over the frontal surface. Sometimes lines of thunderstorms occur above and nearly parallel to a cold frontal surface. More often, particularly over the central United States, long lines or zones of thunderstorms develop in the warm air many tens of kilometres, sometimes several hundred kilometres, ahead of the cold front. The tendency of these so-called prefrontal squall lines to be more or less parallel to the front has suggested that they have been initiated by a dynamic mechanism related to the front.

In the tropics, weather fronts of the kinds so commonly noted at higher latitudes are almost never observed. Air masses of contrasting temperature do not come into contact, as is the case at the polar front, when air from the polar regions encounters air from the tropics. Nevertheless, the regions of maximum thunderstorm frequency occur in equatorial and tropical regions. These storms are triggered by air rising as a result of converging wind

systems. When the northeast trade winds meet the southeast trades, the air at the zone of confrontation must rise. Because it is both moist and unstable, showers and thunderstorms are produced in abundance.

Disturbances in the low-altitude wind field may lead to convergence and ascending air. Such disturbances occur often both in equatorial areas and at higher latitudes and give rise to cumulonimbus clouds and thunderstorms.

Climate

This topic should be treated in a minor way as it is covered in Social Science. It is important to clearly establish the climate zones of PNG so that students are able to relate the climate regimes to the ecological concepts introduced in Module Ecology.

It is essential that this module on weather and climate be done before Ecology.

Draw and label the climatic regions on a world map, or obtain a world climate map, and discuss the different climatic zones with the students.

Highlight the different types of climate and the effects on the different regions of the world.

Students may conduct research about one climatic type and present their findings to the class.

Discuss traditional methods of observing and keeping weather and climate records.

Greenhouse effect and global warming

This topic is covered in Social Science. It is therefore important that lecturers do not repeat the social aspects of this issue.

In this module lecturers should restrict their teaching and discussion to the scientific aspects of the greenhouse effect and the possible effects of global warming. **Global warming has not been conclusively linked scientifically to current human activities.** There are many instances of far worse global warming episodes in the Earth's paleohistory.

It should be made clear to students and lecturers alike that there is a lot of confusion and misunderstanding in the general populace about global warming. **Do not confuse the two terms. The greenhouse effect is a concept; global warming is a consequence of the first!** The greenhouse effect is a necessary part of our Earth's climate. **If there was no Greenhouse effect we would all become extinct!** Global warming occurs due to scientific principle of the greenhouse effect. **We need some global warming or we will all freeze to death.**

Students should understand that ozone, a molecule of three oxygen atoms (O_3), carbon dioxide (CO_2) and methane (CH_4) are the main gases that affect the **greenhouse effect**. If there is too much CO_2 or CH_4 then **global warming** may occur. If there are increased "holes" in the ozone layer then global warming may also occur.

Some discussion questions/activities that the lecturer might initiate:

What evidence is there for global warming?

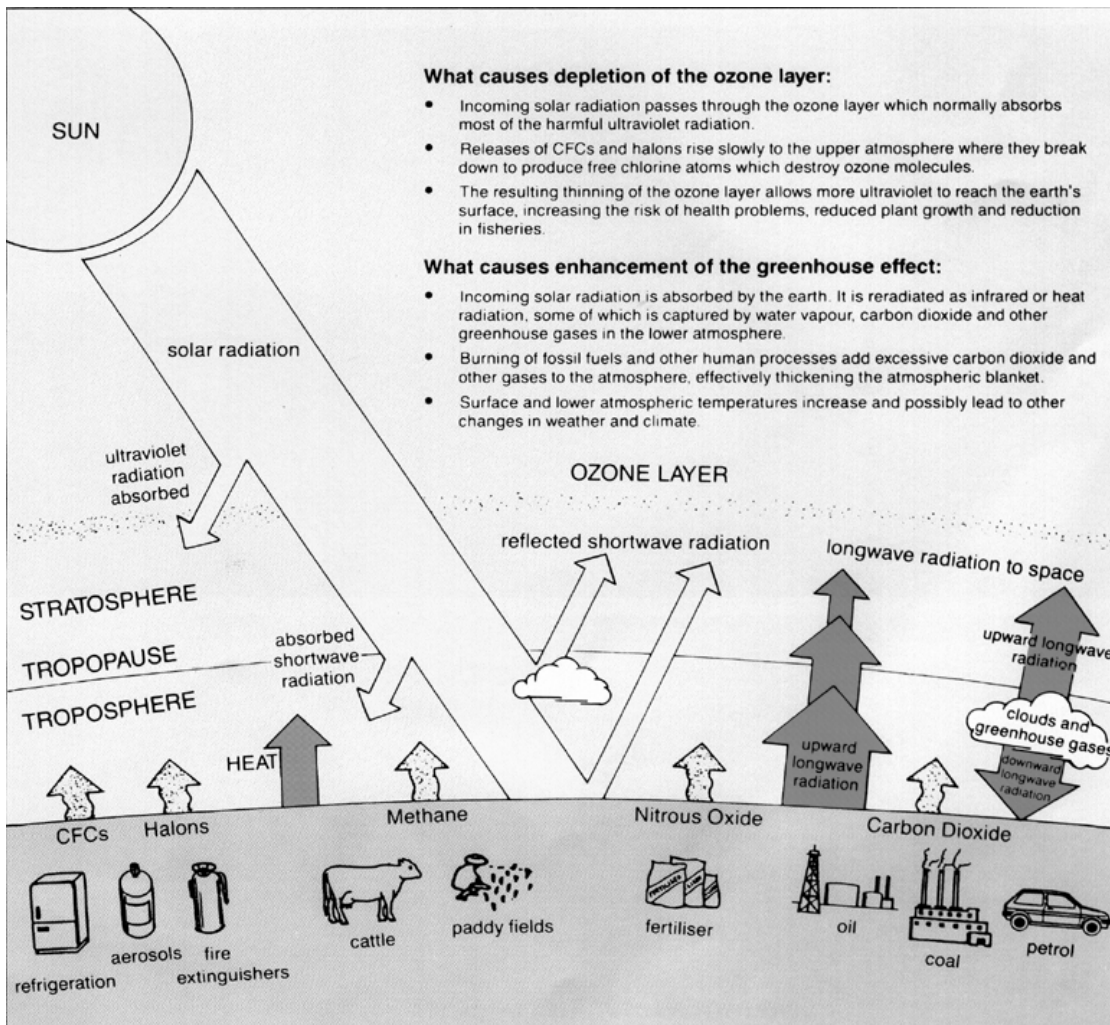
What organisations actively campaign about global warming? What are their objectives?

Is there any evidence of sea level rise due to "excess" global warming in PNG?

What other natural phenomena may cause the sea level to rise or the land to sink?

Are there any human activities in PNG that contribute to global warming?

Is cancer related to the greenhouse effect? (If you have done your homework, you will see that this question is ridiculous!)



Factors affecting the greenhouse effect and ozone layer in the Earth's atmosphere.

(From: Bureau of Meteorology, Australia)

Sea level rises

This is another emotive issue that may be left to the Social Scientists, but as Science lecturers we should ensure that students understand the scientific aspects and mechanisms. In PNG there is more effect from plate tectonics and associated land movement than from ant sea level rises. You only have to look at the raised beaches and reefs along many of the coastlines of PNG!

Suggested student activities

Water cycle

1. Boil some water in a container with a thermometer placed in the water. Observe small bubbles forming at first and large bubbles coming to the surface when the water boils.

Read and record the temperature at regular intervals. Draw a graph of the temperature changes against time. Hold a cold metal or glass container in the steam and observe what happens. Explain all of your observations in terms of energy and the behaviour of water molecules.
2. Place some dry sand in the bottom of an empty soft drink bottle and use a stick to pack the sand down. Place some fine soil or clay in another bottle and pack it down also so that the top of the soil is at the same height as the sand. Now pour equal quantities of water into each bottle. Explain your observations.
3. Pour some water on a grassed area, a footpath, a sandy area and a freshly dug garden soil area. What do you notice? Explain why there is a difference.
4. If there is a river or stream nearby devise a way of measuring the speed of the water flowing past a point. Estimate the cross-sectional area of the water in the stream and calculate the volume of water flowing in the stream in cubic metres per second. How much water would flow in a year?
5. Using simple materials such as a dish and pieces of glass make a simple solar still, i.e., use heat from the sun to evaporate sea water or dirty water and condense and collect the evaporated water.
6. Cut up a drawing with labels of the Water Cycle. Put it back together, piece by piece, explaining to a partner as you do so, what each of the processes involves.
7. Write a short speech that you could give to a group of villagers who asked you for advice about where to put down a well for the village. You should mention groundwater and water table, effect of toilets, pollution, etc.

Weather

1. Design and make a simple rain gauge from discarded soft drink bottles and/or other materials. A good gauge has a large collection area and a small diameter measuring container (why do you think this is so?). Calibrate your gauge so that it accurately records rainfall. (Improvisation).
2. Design an investigation, which uses a thermometer or thermometers, to find out the difference in temperature between a sunny location and a shady location. Carry out your investigation and report your findings. Find out how a maximum and minimum thermometer works.
3. Investigate weather instruments and explain to your partner how each works. Research humidity and air pressure and design a method for measuring each of these in your area.
4. With your colleagues, set up a weather station at your college and record your readings over a period of at least a week. Collect weather reports from the

- newspaper, radio, TV, etc. and compare your readings with the official reports. Account for any differences.
5. Investigate the traditional ideas about weather and weather patterns. Write down all the different ideas you can find. Make a list of the traditional ways in which such things as cloud patterns, etc. are described.
 6. Research and organise group discussions on topics such as: "Can weather affect your personality", "Animals such as ants can be used to predict the weather", "Why do fishermen know so much about the weather", "Weather forecasts are very reliable", "How are thunder and lightning are related?"
 7. Collect a series of weather maps from newspapers and explain to your partner what each symbol means and how the weather changes over a short period of time such as a few days.
 8. Examine a map of the world and explain why deserts, tropical rainforests occur where they do on each of the continents.
 9. Write a story about some weather phenomenon (e.g., rainbow, cloud, thunder) which would be suitable for Grade 5 children. The story could tell a traditional explanation or a modern explanation of the phenomenon. *(This activity may be best left for Physical Science as it is covered in that Unit).*

E5 Earth Science

Rationale

Studies in Earth Science provide a clearer understanding of the nature of our planet and its dynamic systems. Many of the natural impacts on lifestyles in PNG are due to the affects of geological processes and the utilisation of earth resources. Fundamental aspects of earth science are studied in this module. An understanding of geology enables students to appreciate the dynamic forces involved in the formation of these islands and the ongoing processes still at work as well as the origin, discovery, use and conservation of mineral and energy resources. This module also aims to prepare students for teaching earth science concepts in the primary curriculum.

This module will involve students in practical and field exercises to enhance their knowledge of the local context of earth science. Relevant content from the Primary science curriculum will be applied in the teaching and learning of this module.

Objectives

At the end of this module students should be able to

1. understand the processes at work in the formation of the islands of PNG;
2. understand and apply geological concepts to everyday situations and observations;
3. observe and record geological phenomena;
4. graphically represent and interpret data obtained first or second hand;
5. apply physical science principles to the understanding of concepts and problem solving in earth science;
6. access information to learn more about the geological history and resources of PNG;
7. give examples of the relevance of earth science to everyday lives and its significant impact in PNG;
8. communicate ideas and concepts of earth science using a variety of reporting formats applicable to teaching; 2
9. propose effective plans for disaster survival for catastrophic geological events; and
10. appreciate the importance of earth science in the understanding, enjoyment, use, management and preservation of the environment.

Main ideas developed

The earth's interior consists of a number of layers, which have been determined by studying earthquake waves.

The earth's crust consists of plates, which are continually moving to produce mountains, oceanic ridges and trenches.

Earthquakes are caused by waves, travelling through the earth or across water, which are produced when parts of the earth suddenly move past each other,

Earthquakes and volcanoes are commonly associated with plate boundaries while some hot spots in the earth's mantle may produce volcanoes within plates.

Volcanoes may be of several types producing various amounts of ash, lava and gas of different composition.

Violent or erratic forms of weather, earthquakes and volcanoes can be very destructive or disruptive and may cause natural disasters.

Content and sequencing

Plate tectonics

Overview of the dynamics of the earth's changing lithosphere with an emphasis on the region affecting Papua New Guinea.

Earthquakes

Introduction to the nature, detection and affects of earthquakes; PNG vulcanological and seismology stations in the Pacific; effects of earthquakes on the natural and built environment.

Volcanoes

Types of volcanoes affecting PNG and the Pacific region; an introduction to igneous rocks; affects of volcanoes on the natural and built environment.

Natural disasters

Past natural disasters in PNG caused by weather, earthquakes and volcanoes (cyclones, droughts, ash falls, gas, tsunamis, structural damage); Case studies - Aitape, Mt Lamington, Rabaul); effects on landform and human habitation; evidence of past disasters.

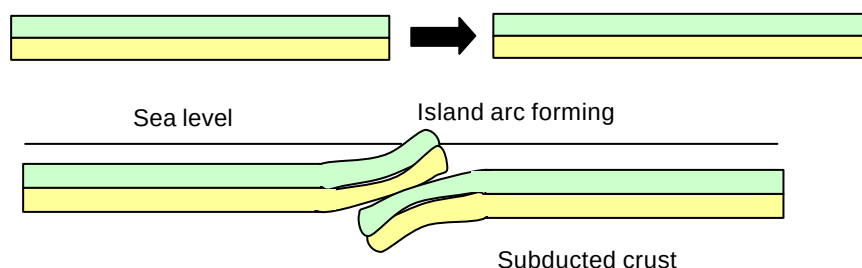
Suggested teaching strategies

Plate tectonics

The use of practical demonstrations using models and concrete examples is essential to introduce the topic of plate tectonics.

Good cheap models can be made using different coloured foam layers or plasticine to represent rock strata. You need to demonstrate oceanic and continental crust in various positions. (Hint: Foam can be cut with a bread knife and painted with acrylic house paint – NOT oil based paint!).

For example in the illustration the top layer is oceanic crust (sima) while the layer beneath is continental crust (sial). As oceanic crust collides with oceanic crust one will go beneath and be subducted. You can demonstrate this easily with foam and students can see what happens. This can then be related to the formation of island arcs such as New Ireland and New Britain in PNG.



The use of a local geologist may also increase student interest to the topic, however you need to be careful to make sure the geologist does not “lose” the students (talks over their heads).

Students may also relate their own experiences with geological events in the area they come from. These experiences might be earthquakes, volcanoes or tsunamis. This is the time to introduce all the effects of the Earth's moving plates.

A display (poster or models) is also useful to relate the tectonic activity with other geological events.

The college should also purchase geological maps and reports, which relate to the area in which the college is located. In this way lecturers are able to improve their own knowledge of the geological history and structures in the area.

Earthquakes

Student experiences should be used to create interest in this topic.

It is good to find out what students already know about some of the terms they hear or read, e.g., Richter scale.

Relate some case studies to students and structure questions about the stories. Students are always interested in stories about disasters and human tragedy. Your library should have books, which give accounts of some of the worst earthquakes in the World. (Refer to the Encyclopaedia Britannica CD ROM for plenty of stories.)

Lecturer Readings

(From Encyclopaedia Britannica, 2001 CD ROM)

Some great earthquakes

About 50,000 earthquakes large enough to be felt or noticed without the aid of instruments occur annually over the entire Earth. Of these, approximately 100 are of sufficient size to produce substantial damage if their centres are near areas of habitation. Very great earthquakes occur at an average rate of about one per year. Among the great earthquakes of the past are those of Lisbon in 1755; New Madrid, Mo., U.S., in December 1811 and January and February 1812; San Francisco in 1906; Tokyo-Yokohama in 1923; the coast of Chile in 1960; south-central Alaska in 1964; T'ang-shan, China, in 1976; and Mexico in 1985. Their devastating effects are briefly described below.

Lisbon

On Nov. 1, 1755, Lisbon was heavily damaged by a great earthquake that occurred at 9:40 a.m. The source was situated some distance off the coast. The violent shaking demolished large public buildings and about 12,000 dwellings. As November 1 was All Saint's Day, a large part of the population was attending religious services; most of the churches were destroyed, resulting in many casualties. The total number of persons killed in Lisbon alone was estimated to be as high as 60,000, including those who perished by drowning and in the fire that burned for about six days following the shock. Damage was reported in Algiers, 1,100 kilometres to the east. The earthquake generated a **tsunami** that produced waves about six metres high at Lisbon and 20 metres high at Cádiz, Spain. The waves travelled on

to Martinique, a distance of 6,100 kilometres in 10 hours, and there rose to a height of four metres.

Effects of earthquakes

Earthquakes have varied effects, including changes in geologic features, damage to man-made structures, and impact on human and animal life.

Geomorphological changes are often caused by an earthquake: *e.g.*, movements, either vertical or horizontal, along geological fault traces; the raising, lowering, and tilting of the ground surface with related effects on the flow of groundwater; liquefaction of sandy ground; landslides; and mudflows. The investigation of topographical changes is aided by geodetic measurements, which are made systematically in a number of countries seriously affected by earthquakes.

Earthquakes can do significant damage to buildings, bridges, pipelines, railways, embankments, and other man-made structures. The type and extent of damage inflicted are related to the strength of the ground motions and to the behaviour of the foundation soils.

In the most intensely damaged region, called the meizoseismal area, the effects of a severe earthquake are usually complicated and depend on the topography and the nature of the surface materials; they are often severer on soft alluvium and unconsolidated sediments than on hard rock. At distances of more than 100 kilometres (62 miles) from the source, the main damage is caused by surface waves. In mines there is frequently little damage below depths of a few hundred metres even though the surface immediately above is considerably affected.

Did you hear the earthquake?

Further effects of interest are the occurrence of earthquake sounds and lights. The sounds are generally low-pitched and have been likened to the noise of an underground train passing through a station. The occurrence of such sounds implies the existence of significant short periods in the *P* waves in the ground (a wave period is the length of time between the arrival of successive crests in a wave train). Occasionally luminous flashes, streamers, and balls are seen in the night sky during earthquakes. These lights have been attributed to electric induction in the air along the earthquake source.

Earthquake magnitude

Because the size of earthquakes varies enormously it is necessary for purposes of relative comparison to compress the range of wave amplitudes measured on seismograms by means of a mathematical device. In 1935 the American seismologist Charles F. Richter set up a "magnitude scale of earthquakes" as the logarithm to base 10 of the maximum seismic wave amplitude (in thousandths of a millimetre) recorded on a standard seismograph (the Wood-Anderson torsion pendulum seismograph) at a distance of 100 kilometres from the earthquake epicentre. Reduction of amplitudes observed at various distances to the amplitudes expected at the standard distance of 100 kilometres is made on the basis of empirical tables. Richter magnitudes M_L are computed on the assumption that the ratio of the maximum wave amplitudes at two given distances is the same for all earthquakes considered and is independent of azimuth.

Richter first applied his magnitude scale to shallow-focus earthquakes recorded within 600 kilometres of the epicentre in the southern California region. Later, additional empirical

tables were set up, whereby observations made at distant stations and on seismographs other than the standard type could be used. Empirical tables were extended to cover earthquakes of all significant focal depths and to enable independent magnitude estimates to be made from body- and surface-wave observations.

At the present time, a number of different magnitude scales are used by scientists and engineers as a measure of the relative size of an earthquake. The *P*-wave magnitude (m_b), for one, is defined in terms of the amplitude of the *P* wave recorded on a standard seismograph. Similarly, the surface-wave magnitude (M_s) is defined in terms of the logarithm of the maximum amplitude of the ground motion for surface waves with a wave period of 20 seconds.

Taken as such, a magnitude scale has no lower or upper limit. Sensitive seismographs can record earthquakes with magnitudes of negative value and have recorded magnitudes up to about 9.0. (The 1906 San Francisco earthquake, for example, had a Richter magnitude of 8.25.)

There is, in effect, no direct mechanical basis for magnitude. Rather, it is an empirical parameter analogous to stellar magnitude. In modern practice, a more soundly based mechanical measure of earthquake size is used--namely, the seismic moment (M_0). Such a parameter is related to the angular leverage of the forces that produce the slip on the causative fault. It can be calculated both from recorded seismic waves and from field measurements of the size of the fault rupture. Consequently, seismic moment provides a more uniform scale of earthquake size. Still another magnitude currently in use is called moment magnitude (M_w). It is proportional to the logarithm of the seismic moment. Given the above definitions, the great Alaska earthquake of 1964 had the values $M_s = 8.4$, $M_0 = 820 \times 10^{27}$ dyne centimetres, $M_w = 9.2$.

Volcanoes

A video is essential to enable students to witness volcanic eruptions (especially if they are not lucky enough to have seen some of the PNG volcanoes erupting first hand!).

All videotapes should be previewed by the lecturer. Structured activities and questions should be based on the video.

There are a number of accounts of PNG volcanoes included in electronic form in the Resources Folder on the Science CD ROM supplied to the College. These summaries have been extracted from WEB sites and compiled for your use.

Models are also essential to demonstrate the structure and composition of volcanoes.

You should also try to obtain volcanic rock samples from the volcanic areas of PNG. Communicate with your colleagues who live near volcanoes, active, dormant or extinct, and ask them to send you some samples!

The University of PNG (geology Department) should also be able to help out!

You can also order rock kits from suppliers in Australia (resource order).

Natural disasters

Again introduce this topic by using the recent case study in PNG, Aitape. There is a good PNG produced video available for students to witness the effects of this tsunami. (It has

been agreed that the tsunami was caused by a large landslide on the sea floor well after the initial earthquake).

There are many documentaries made for television about tsunamis. National geographic has produced a series for each geological phenomena. The BBC has also produced excellent series on geology topics. These should be procured for the college.

Tsunamis

(Reading from Encyclopaedia Britannica, 2001)

Tsunamis are also called **seismic sea wave**, or tidal wave or catastrophic ocean wave. They are usually caused by a submarine earthquake occurring less than 50 km (30 miles) beneath the seafloor, with a magnitude greater than 6.5 on the Richter scale. Underwater or coastal landslides or volcanic eruptions also may cause a tsunami. The term tidal wave is more frequently used for such a wave, but it is a misnomer, for the wave has no connection with the tides. (The term tidal wave actually refers to a wave moving up an estuary or river due to the tide rising. The funnelling effect creates a wave.)

After the earthquake or other generating impulse, a train of simple, progressive oscillatory waves is propagated great distances at the ocean surface in ever-widening circles, much like the waves produced by a pebble falling into a shallow pool. In deep water, the wavelengths are enormous, about 100 to 200 km, and the wave heights are very small, only 0.3 to 0.6 m (1 to 2 feet). The resulting wave steepness, or ratio of height to length, ranges between $3/2,000,000$ and $6/1,000,000$.

This extremely low steepness, coupled with the waves' long periods that vary from five minutes to an hour, enables normal wind waves and swell to completely obscure the waves in deep water. In any progressive oscillatory wave, the actual water motion at the surface consists of a vertical orbit with a diameter equal to the wave height, coming full circle during the period of the wave. Thus, a surface-water particle or a ship in the open ocean experiences the passage of a tsunami as an insignificant rise and fall of only 0.3 to 0.6 m, lasting from five minutes to an hour.

The surface orbital motion of any progressive oscillatory wave is transmitted diminishing downward through the water, becoming insignificant at a depth below the surface equal to approximately half the wavelength. Tsunamis, however, being enormously longer than even the greatest ocean depths, experience significant retardation of orbital motion near the seafloor and behave as shallow-water waves regardless of the depth of the ocean the waves are propagated across. The velocity of shallow-water waves is controlled by this friction with the bottom, obeying the formula

$$c = \sqrt{gD}$$

in which c is the wave velocity, g is the acceleration of gravity, and D is water depth. This relationship was used to determine the average depth of the oceans in 1856, long before many deep-sea soundings had been taken. Assuming an average velocity for seismic sea waves of about 200 m per second (450 miles per hour), an average oceanic depth of about 4,000 m is obtained; this figure compares very well with the modern estimate of 3,808 m. The relationship has enormous practical value, enabling seismologists to issue warnings to **endangered** coasts immediately after an earthquake and several hours before the arrival of the tsunamis.

As the waves approach the continental coasts, friction with the increasingly shallow bottom reduces the velocity of the waves. The period must remain constant; consequently, as the velocity lessens, the wavelengths become shortened and the wave amplitudes increase, coastal waters rising as high as 30 m in 10 to 15 minutes. By a poorly understood process, the continental shelf waters begin to oscillate after the rise in sea level. Between three and five major oscillations generate most of the damage; the oscillations cease, however, only several days after they begin.

Tsunamis are reflected and refracted by nearshore bottom topography and coastal configurations as any other water waves. Thus, their effects vary widely from place to place. Occasionally, the first arrival of tsunami at a coast may be a trough, the water receding and exposing the shallow seafloor. Such an occurrence in Lisbon Port, on Nov. 1, 1755, attracted many curious people to the bay floor; and a large number of them were drowned by the succeeding wave crest that arrived only minutes later. Perhaps the most destructive tsunami was the one that occurred in 1703 at Awa, Japan, killing more than 100,000 people. The spectacular underwater volcanic explosions that obliterated Krakatau (Krakatoa) Island on Aug. 26 and 27, 1883, created waves as high as 35 m in many East Indies localities, killing more than 36,000 people.

Suggested student activities

Plate tectonics

1. Research the Earth's internal structure. Use recycled materials to make a model of the earth with part cut away to show the internal layers. Use the model to explain to your partner the composition and significance of the layers
2. Find out what plate tectonics is. Explain to your partner why Alfred Wagener's Theory strongly supports plate tectonics.
3. Research the evidence of plate tectonics and what underlies the plates then explain to your partner.
4. Demonstrate the concept of convection current to your partner.
5. Research and label the main plates of the world on your map. Cut along the plate boundaries and demonstrate the plate movements as suggested on the plates.
6. Identify geographical features of constructive, conservative and destructive plate boundaries of the world. Using the plate boundaries of PNG identify on your map constructive, conservative and destructive plate boundaries. Discuss types of geological features present.
7. Research whether the earth is expanding or contracting and explain to your partner.
8. Make a jigsaw puzzle on the major plate boundaries of the world.

Earthquakes

1. Research earthquakes. Draw a map of the world and on it shows where the main earthquake and volcanic activity takes place. Explain to your partner why this exists.
2. Research the geology of PNG. Explain to your partner the pattern of earthquakes and volcanoes in PNG and explain why this pattern exists.

- 3 Make a model of a seismograph. Explain to your partner how it works.
- 4 Research earthquake waves. Draw and label the different types of waves. Explain to your partner how the studies of these waves allow scientists to determine the internal structure of the earth.
- 5 Demonstrate how earthquake waves move by using a slinky spring and/or a rope.
- 6 Find out what Tsunamis are. Explain the kind of disasters associated with tsunamis using Aitape as reference.
- 7 Research the Richter Scale and the Mercalli Scale for measuring the effects of earthquakes. Explain to your partner what is measured and how the scale is used

Volcanoes

- 1 Research the different types of volcanoes, their structure, formation and location around the world. Relate this information to PNG by locating the active volcanoes in PNG on a map and explaining to your partner why they occur in this pattern.
- 2 Research types of materials ejected from an erupting volcano. Make a list of all these materials and then categorise them according to their forms. (Gases, liquids & solids)
- 3 Make a cutaway scale model of a stratovolcano out of recycle materials. Use your model to explain to your partner the characteristics of such volcanoes.
- 4 Research and explain to your partner the differences between extinct, dormant and active volcanoes. On a map of PNG show the location and names of some of each of these types of volcanoes.
- 5 Collect newspaper clippings of volcanic events in PNG. Research past volcanic disasters. Explain to your partner how it is planned to avoid future volcanic disasters in PNG.
- 6 Obtain a copy of the brochure from the Rabaul Volcano Observatory and use it to explain to your partner how the observatory monitors the volcanic activity and on what basis it issues warnings of potential eruptions.

Natural disasters

- 1 Research types of disasters caused by earthquakes and volcanoes.
- 2 Watch a videotape on earthquakes and volcanoes then discuss how dangerous these are to living organisms.
- 3 Interview a person who once lived in Rabaul about what it was like for them to evacuate Rabaul during the 1994 eruption.
- 4 Survey the landscape near Vulcan and discuss with your partner the succession rate of plants. (For Kabaleo students).
- 5 Observe and record what were destroyed during the 1994 eruptions.
- 6 Discuss the significance of monitoring stations near volcanic areas.

- 7 Research the types of buildings near volcanic areas in PNG. Explain why they are constructed the way they are?
- 8 Design a short and a long-term evacuation plan for a volcanic eruption near your place of living.

Answers to selected questions



Exercise 1.1 The earth's crustal plates

View a suitable video or references in your library to answer the following questions.

- 1** *Why is a mid ocean ridge in the middle of the ocean?*
The present large oceans have developed as continents separated along a ridge that is generating new crust. This ridge is now near the centre line of the major oceans.
- 2** *What produces the force that pulls the plates apart?*
Convection currents in the upper mantle cause the crust to ride along on a “conveyor belt”.
- 3** *Why do island chains such as those of PNG run in different directions?*
There are a number of plate boundaries that run in different directions.
- 4** *What happens when plates move past each other?*
The movement generates energy release in the form of earthquake waves.
- 5** *What do we mean when we say the plates “stick”?*
Sometimes the plates do not move freely past one another and will suddenly let go resulting in large movements and large releases of energy – big earthquakes.
- 6** *PNG has several earthquakes every day. Why?*
PNG is situated at the margin of several very active plate boundaries hence many earthquakes occur as plates move and release energy.
- 7** *Why are tsunamis experienced thousands of kilometres away from the epicentre of an earthquake?*
The energy of an earthquake is transferred to the sea as a large ocean wave and then travels at high speed across the oceans to arrive at places a long way away.
- 8** *How frequent are earthquakes in PNG? Why?*
See question 6. Very frequent! There were 43 large earthquakes (>5 on the Richter Scale) in ONE WEEK in New Britain and New Ireland from Nov 16 to 23 in 2000.
- 9** *Why do volcanoes form at plate boundaries (subduction zones)?*
When plates collide one may go under another and melt to produce magma. The magma rises to the surface and forms volcanoes.
- 10** *Do you get the feeling that lava is hard or soft?*
Lava looks soft “like water” when seen flowing but it cools to form a very hard rock.
- 11** *Why was Krakatau so violent?*
See Readings. As the caldera collapsed the sea rushed into the vent and caused a secondary and very violent explosion.
- 12** *What is a “glowing cloud”?*
This term refers to pyroclastic flows that are very hot clouds of ash, gas and steam, which rush down the side of an erupting volcano. These clouds move so fast (100s km/hr) that people cannot escape.



Activity 12 Plate tectonics of PNG

Questions

- 1** How do the positions of the active volcanoes D relate to the subduction zones?

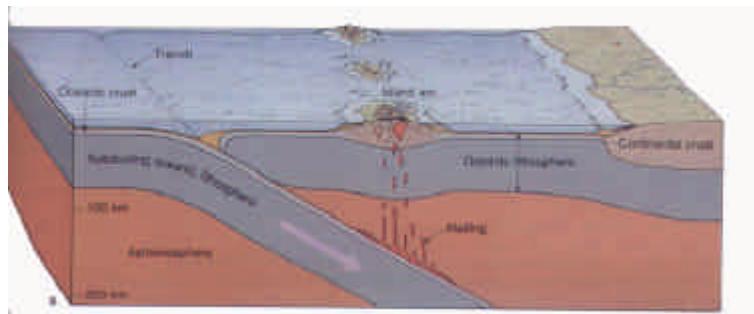
The active volcanoes appear in front of the direction of movement of a plate that is “going under” (being subducted). There is usually a deep trench and an island arc in these zones.

- 2** *Would you expect any more volcanoes in PNG in the future? Explain your answer.*

Because PNG is in a very active tectonic zone volcanoes will continue to appear.

- 3** Draw a section where there is an active volcano to show how they (volcanoes) might be generated.

This section is typical of convergent plate collisions seen in the islands regions of PNG. New Britain, New Ireland and North Solomon Islands were all formed by the collision of an oceanic plate with another oceanic plate.



From: Tarbuck and Lutjens (1994). *Earth Science* (7th Edn). Macmillan: New York. (p. 223).

- 4** What is the approximate age of these past eruptions? Hint: You will need to look at the legend on the geological map of PNG.

The eruptions in PNG range from Triassic (200 million years ago) in the main island to the present active volcanoes in many parts of PNG. The Rabaul caldera (Simpson Harbour) was formed about 600 years ago during a giant explosive eruption that ejected about 18 cubic kilometres of ash, lava and pyroclastics. Deposits from this eruption have been identified covering most of the Gazelle Peninsula. Almost certainly this eruption would have been as devastating as the famous Krakatau Island eruption of Indonesia.

Exercise 1.3

Origins of earthquakes

- 1** *How might earthquake epicentres relate to subduction zones and trenches?*

As plates move past one another stresses are built up by sticking plates. The sudden movement of the plates releases the stresses and energy is transmitted through rocks (earthquakes) and water (tsunamis). The **focus** is the point at which the break or movement occurs. At subduction zones the oceanic plate is sliding under another crustal plate (oceanic or continental). As these plates move to great depths (subducted) the zone of earthquake epicentres ranges from very shallow (less than 33km) to very deep (up to 500 km). The shallower earthquakes are generally felt more at the surface and damage is greater from these earthquakes.

- 2** *At what depth would you expect earthquake epicentres South of Manus Island?*

The epicentre should be shallow as Manus is near a diverging plate boundary. Earthquakes are generally shallow in these zones.

- ### 3 What do you associate with shallow sea floor earthquakes?

Mid-ocean ridges are associated with shallow sea floor earthquakes. These are found in most large oceans of the World. Shallow earthquakes may also be generated by submarine slides and faulting along coastlines such as occurred east of Aitape.



Exercise 1.4 **Predicting earthquakes**

- 1 *Where might shallow earthquakes occur in relation to the plates and boundaries?*

Shallow earthquakes will occur at **all** plate boundaries. They are common at divergent plate boundaries (mid ocean ridges and rift valleys) and convergent continental-continental boundaries, e.g., Himalayas and the Alps.

- 2 *Where might deep earthquakes occur in relation to the plates and boundaries?*

Deep earthquakes will occur along plate boundaries where subduction is occurring.

- 3 *Which places in PNG would you expect to experience the most serious earthquakes?*

The most serious earthquakes will occur along transform and continental-continental plate boundaries, that is, where one plate slides past another or collides without subduction, e.g., Turkey. A good example of a transform plate boundary in PNG is that along the northern coastline of PNG as an extension of the Markham valley. Some shallow earthquakes along subduction zones may also be quite serious at times but are not very common. For example, a magnitude 8.0 earthquake occurred near Pomeo (East New Britain) on 17th November 2000.



Exercise 2.1 **Major earthquakes**

Refer to the Reading: **Major Earthquakes** and answer the following questions.

- 1 *How are faults, foci and epicentres related?*

Movement along faults causes earthquakes. The exact location of the movement is called the epicentre. The point on the Earth's surface vertically above the epicentre is the focus of an earthquake.

- 2 *What does the term elastic rebound mean?*

Even solid rocks have some elasticity (springiness). When rocks are stressed and bent and suddenly break the sudden movement may cause some rebound due to the "springiness".

- 3 *Faults that are experiencing no active creep may be considered safe. Is this true or false? Give reasons for your answer.*

In an active plate zones, active creep is necessary to relieve stresses. If there is no creep or movement the sudden release as rocks move will be more severe generating a greater magnitude earthquake.

- 4 *Compare the causes of the damage in the 1988 Armenian and the 1985 Mexico City earthquakes.*

In both earthquakes the epicentre was very shallow resulting in extensive damage at the foci and surface. The Armenian earthquake is in a convergent plate zone (continental-continental boundary) and the Mexico City is on an intra-plate zone, that is, not on any active plate boundary. The Mexico City Earthquake was due to subsidence of a Basin.

- 5 *How can an earthquake of lower magnitude possibly cause more damage than one of higher magnitude?*

Earthquakes of lower magnitude will only cause more damage if they are shallow and directly below the area affected. The extent of damage is also dependent on the rocks and sediments in the area. Hard rocks transfer energy to buildings efficiently causing far more damage than sand or ash foundations. However, in swampy areas such as Mexico City, the sediments become liquid and buildings sink!

- 6 *Devise a model for a primary lesson to demonstrate the elastic nature of rocks and the sudden release of energy that results when rocks suddenly break or move against each other.*

Load a flat wooden plank or ruler over the edge of a table. The ruler bends until it reaches fracture point. This is similar to rock behaviour. Students could also try other materials.



Exercise 22 Earthquakes and plates

Compare Figures 1.1 (Tectonic plates of PNG) and 2.5 (Epicentres of Earthquakes).

- 1 *What relationship is there between the density of earthquake epicentres and the plate boundaries?*

Earthquakes are more frequent at plate boundaries where movement is rapid, several centimetres per year! Subduction zones produce many earthquakes over a large area due to the plunging plate, from shallow to very deep.

- 2 *Where do the deeper and shallower earthquakes occur?*

Deeper earthquakes occur more frequently in subduction zones. Some intra-plate regions, where sediment load is high, may also produce less frequent deep earthquakes.

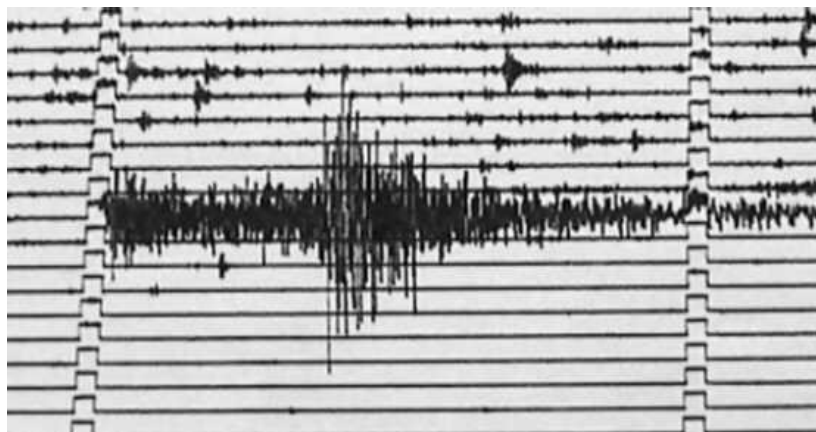
- 3 *Explain the occurrence of deep earthquakes by drawing a labeled diagram of a subduction zone.*

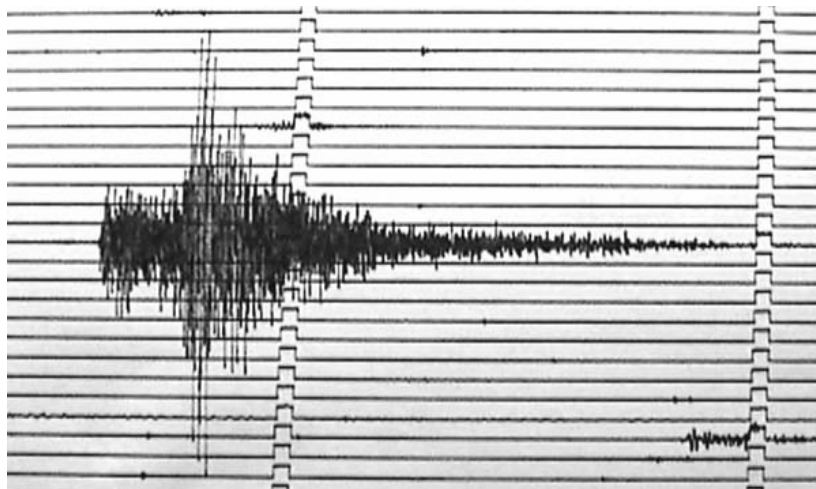
See answer for Activity 1.2, Question 3 – Diagram of a subduction zone.



Exercise 23 P and S waves

- 1 *Mark the points that record the P and S arrivals on each graph.*





- 2 Estimate the time difference between the P and S wave arrivals for each Station.

First graph: $S - P = (2.9 \text{ cm} / 7.8 \text{ cm}) \times 60 \text{ sec} = 22.3 \text{ sec}$

Second graph: $S - P = (1.0 \text{ cm} / 6.1 \text{ cm}) \times 60 \text{ sec} = 9.8 \text{ sec}$

- 3 Which Station do you think was closer to the epicentre? Explain your answer.

The second graph is from the closest station because there is less difference between the arrival times of the P and S waves.



Exercise 24 The Aitape, PNG disaster

View the video on the Aitape disaster and read the case study ***The PNG Tsunami of July 17, 1998 Papua New Guinea Tsunami*** (Readings) and discuss the following questions in groups. Report to the whole class.

Essential Reading: Davis, H. (1999). *Tsunami PNG 1998*. University of Papua New Guinea: Port Moresby has a comprehensive report that will provide students with additional readings. All college libraries should have copies of this booklet.

- 1 How much warning did the inhabitants of Aitape have?

No media warning was given as the tsunami arrived about 15 minutes after the earthquake. Some villagers did witness the initial lowering of the sea level. Any sudden appearance of an extraordinary low tide is a good indication that a tsunami may be approaching. This is a good time to run to high ground!

- 2 Where was the epicentre located?

The epicentre was located about 30 km East of Aitape along the plate boundary of the Asian-Australian and Pacific plates.

3 *What geological event most likely caused the tsunami?*

The earthquake most likely triggered a secondary event, a submarine landslide, which generated the large tsunami. The landslide may have been closer to Sissano lagoon than the epicentre.

4 *Describe the nature of the earthquake?*

The earthquake was generated by movement along a fault associated with the plate boundary that runs parallel to the coastline. The magnitude was 7.0 on the Richter Scale. As this fault has some transform movement the earthquake was probably shallow therefore more energy would be released near the surface.

5 *What is “run-up” and why is this of much interest to scientists?*

This is the maximum vertical height the wave reaches on-shore. Higher waves will penetrate further inland and cause widespread erosion and damage.



Exercise 25 **What are tsunamis?**

Read **Frequently Asked Questions** from Pacific Tsunami Museum WEB site. A copy of these is in the readings. Answer the following questions.

1 *What causes a tsunami?*

A seismic disturbance displaces the water column creating a rise or fall in the level of the ocean above. Tsunamis may also be caused by volcanic eruptions or landslides below the sea level (typically along the edges of continental shelves).

2 *How is a tsunami wave different from a normal wave?*

The magnitude of the disturbance generating the wave is the major difference. The usual sea waves are caused by wind and the size (amplitude, wavelength and frequency) depends on the strength and duration of the wind. Tsunamis are only small in amplitude (wave height) but long in wavelength. They may travel at up to 800 km/hour. The wave height suddenly increases as the wave moves towards shallow water.

3 *What is run-up?*

The maximum vertical height reached by a tsunami wave as it breaks on the shoreline. The maximum horizontal is called inundation.

4 *How are tsunami wave heights measured?*

The height is not easily measured. The height of debris and the extent of salt damaged vegetation are used as a measure of height.

5 *How long does it take a tsunami to reach land?*

As tsunamis travel at up to 800 km/hr over deep water it does not take them long to cross the oceans. A tsunami can cross the Pacific in less than one day! Local tsunamis will reach the coastline in minutes!

6 *What is the Tsunami Warning System?*

Accurate and well-maintained seismological stations and tide monitoring gauges are linked throughout the Pacific to the Pacific Tsunami Warning System (PTWS). After computing the data warnings are issued giving arrival times at various exposed coastal places around the Pacific.

7 *What is the difference between a Tsunami Watch and a Tsunami Warning?*

A Tsunami Watch is automatically declared by the Warning Centre for any large earthquake (>7.0) from a potential tsunami generation area. A Warning indicates that a wave has been detected by one of the tidal gauge stations and the wave is on its way!

8 *What is the “wrap-around” effect?*

As a large tsunami approaches land the wave may be bent (refracted) and travel between islands or “around corners”.

9 *How many waves are there in a tsunami?*

There is a series of waves referred to as a “tsunami wave train” which have a period of a few minutes to over an hour. It is important NOT to return to a coastal area after the FIRST wave! A good analogy is the effect seen when a pebble is thrown into a pond. A large wave is seen travelling outwards followed by a series of diminishing waves.

10 *How does a tsunami behave as it approaches land?*

The shape of a tsunami wave depends on the shape of the seafloor and the coastline. As the wave runs into shallows the height will increase from a metre or less to over 20 metres. Bays will also amplify the effect and the wave can be much higher than nearby coastlines. An offshore reef may provide some protection by dissipating some of the energy of the wave. Wind generated waves may increase the height of a tsunami. Seiche waves may also be experienced due to the “rocking” action of reflected waves off nearby islands and coastlines.

11 *How would you determine an inundation/evacuation area?*

Worst-case tsunamis are used to calculate the possible wave heights and inundation areas and plot these as contours onto coastal maps. People should then be advised to either not live in these areas or to develop early warning systems and well known evacuation procedures.



Activity 3.1 *Volcanoes: where and why?*

A. Where are volcanoes located around the Pacific?

1. *Write down the names of some PNG volcanoes?*

Karkar Island, Mt. Lamington, Manam Island, Mt Ulawun, Mt Turvuvur, Ritter Island, Long Island.

2. *Table 3.1, on page 25, lists the locations of 30 volcanoes. Use latitude and longitude to find and mark the position of each volcano on the world map, figure 3.1, on page 26. Write the name of the volcano next to each location.*

Complete as class exercise on map. Some students may need help with mapping skills.

3. *Where are most of these volcanoes located? Describe the tectonic location. Refer to your studies of the Earth’s major tectonic zones.*

Most are located along an arc from the north of New Britain to the PNG mainland. These are along the subduction zone between the Solomon and South Bismark plates. Mt Lamington lies near the margin of the Indo-Australian Plate and the Solomon Plate. There are also active volcanoes on Bougainville. These are formed due to the subduction zone between the Pacific and Solomon Sea Plate.

B. Why are volcanic rocks different from each other?

1. *Examine the samples (labelled A to F) of the igneous rocks from PNG. These rocks are volcanic. List ways in which you think these rock are different from each other. Compare your list to those of others.*

The rocks differ in colour, texture, grain size and composition. They range from light to dark in colour, fine grained to coarse (containing fragments). Texture is glassy; holey (vesicular); fragmented (clastic) and vary from “light” to “heavy” in weight.

2. *When a volcano erupts, rock material may either be ejected explosively or poured out as sticky or runny lava. What characteristic of a rock would tell you how fast it cooled?*

The grain size indicates the rate of cooling. Larger grains or crystals take longer to cool while glassy rocks cool very fast (during eruption).

3. *The types of eruptions are related to the composition of the magma. Look again at the colour and grain sizes of the rock samples labelled A to F. What type of volcanoes would you expect in PNG?*

Based on the samples the volcanoes of PNG would be dominantly cinder and composite type volcanoes which produce ash, pyroclastics and some lava. These volcanoes tend to be explosive at times. The lava is blocky and does not flow readily.

4. *Look at a geological map of PNG. Write down the major types of volcanic rocks and the locations. What are the predominant lava types in PNG?*

Based on the samples the volcanoes of PNG the light coloured fine-grained rocks would be acidic (rhyolite and trachyte lavas) and the medium coloured would be intermediate (andesite lavas). Occasionally deep magma may rise to the surface to produce basic (dark) lava which cools to form basalt.

5. *The complete chemical analyses (by percent) of two volcanic rocks that came from different volcanoes are listed in Table 3.2 on page 27.*

Which of the elemental oxides differ by the largest amount?

The silicon dioxide (SiO_2) differs by the largest amounts and FeO, MgO and CaO differ by lesser amounts.

What could you predict about the type of eruptions at Yellowstone National Park and Hawaii?

The Yellowstone eruptions have acidic lava (>66% SiO_2) therefore the eruptions would be explosive producing ash, pyroclastic flows and some lava. On the other hand the Hawaiian volcanoes produce basic magma which is seen as abundant basalt lava flows which flow easily.

C. Where are the volcanoes that produce high, medium and low silica lava?

Table 3.1 also lists the SiO_2 composition of the 30 volcanoes plotted in part A. Now use coloured pencils or biro to mark the volcanoes as high, medium or low in silica.

Where are most of the red dots, blue dots and black dots? Explain the locations and silica compositions with reference to the composition of crustal plates and the plate tectonic model.

The high silica volcanoes are in Indonesia, Wyoming and Alaska. These are produced from shallow magma at plate boundaries.

The low silica (basaltic) magmas are produced mostly at the mid-ocean ridges (Somoa, Tahiti and Galapagos) and hot spots (Hawaii).

The intermediate volcanoes dominant the Pacific Rim or Ring of Fire! These are mainly located near subduction zones.



Exercise 3.1

Read *Krakatau: The 1883 eruption.*

1. Summarise the main events of that fateful day, 27th August, 1883.

See readings.

2. What was the main material ejected from this volcano?

Ash, pumice and pyroclastic flows.

3. What evidence exists today to support the type of eruption?

Ignimbrite deposits in the sediments.

4. Draw a series of sketches to illustrate the eruption sequence.

Refer to the readings (p.3)

5. What effects did the eruption have on the people of the area, ships at sea and neighbouring countries?

Inhabitants of nearby islands as well as Krakatau perished - 36 000 died mainly due to tsunamis up to 24 metres high. The sound was heard in Australia and the ash caused darkness for days in the region. Ships at sea were not harmed, as tsunamis do not affect them in deep water. Ash hurricanes were felt up to 100 km away. Winds reached 300 km/hr.



Exercise 3.2

Read *The Darkness Legends: A geological investigation in PNG.* (Blong, R.J., 1982) adapted by Gaul, A.J. (1998).

1. What are the frequent themes in the stories or legends?

Ash fall and damage to gardens with loss of daylight for several days. People were not killed if they stayed in their houses.

2. What are the variations between the stories?

The story from the Southern Highlands indicates that it was dark for 7 nights. The other stories do not give a time. The fallout is described as ash in some places and sand in others. (The sand probably indicates a closer location to the source.) Sometimes there was rain with the fallout. Some stories mention “wood chips”. Maybe a forest “exploded” during the initial eruption and was scattered over the nearby areas.

3. *Are the stories linked to an actual event and is there a scientific explanation for the stories?*

The actual event was most probably the catastrophic explosion of Long Island some 200 to 300 years ago. The best evidence is the existence of pyroclastic deposits and ash falls (Matupan Beds) on Long Island and ash deposits in the Highlands (Tibito Tephra). The age was determined from trees buried at the base of the Matupan Beds on Long Island (230 ± 75 BP to 200 ± 65 BP).

4. *What produced the Darkness ash cloud and how far did the ash cloud spread?*

Large volumes of ash were ejected and carried by the prevailing wind from Long Island to the Highlands. The ash clouds would have blocked out the sun for days depending on the length of time the volcano erupted. If we measure the map on Page 6 of “*The Darkness Legends*” reading we find that the ash spread westwards for about 500 km.

5. *Do you think there was any effect on other parts of the world?*

The effect elsewhere would have been limited to some ash in the higher atmospheric levels (stratosphere). This ash would produce some colouring of the sunsets in nearby regions.

6. *Read the account of the Long Island eruption. Summarise the main points. Draw and label the main volcanic features of Long Island.*

Read pages 7 to 10 of the Readings “Darkness Legends”.

7. *What effects would a similar eruption have in your area?*

An eruption of this magnitude would cause a lot of damage and death. The eruption could be likened to that of Krakatau (Indonesia) in which 36 000 died. Huge tsunamis would be expected and residents of all nearby islands would probably perish. In a big eruption areas close to any volcano are not safe.

Review

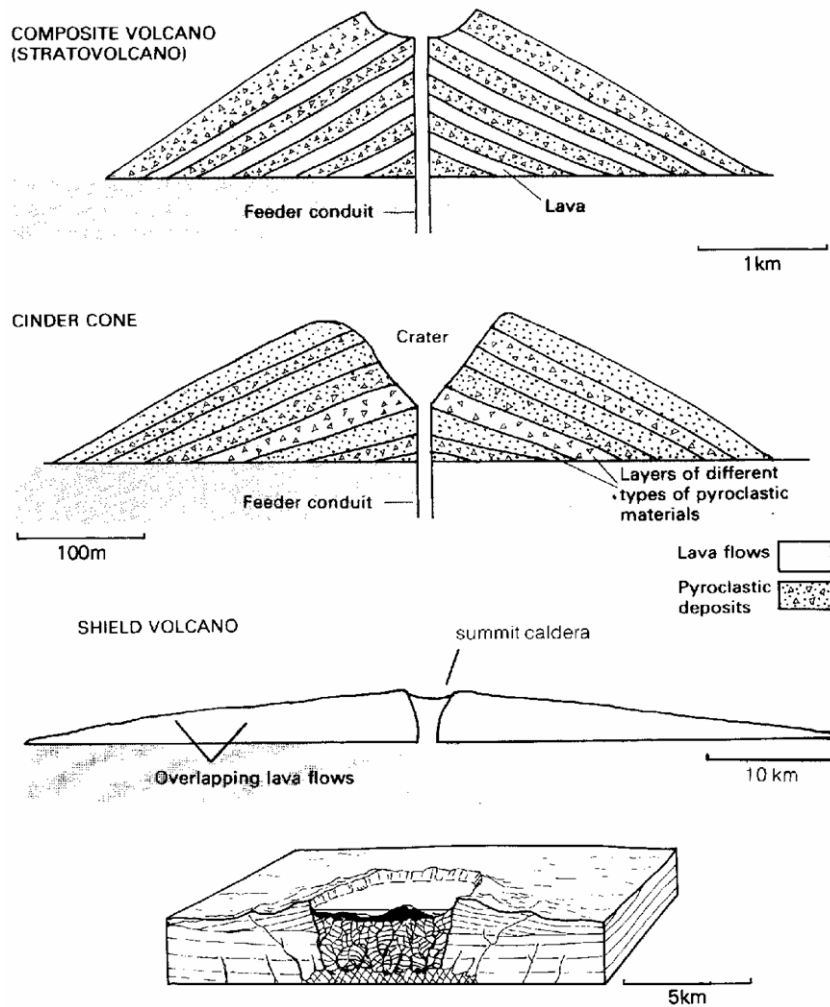
- 1 *List the major types of eruptions.*

Central-Type Eruptions: Shield volcanoes, Cinder cones and Composite cones

Fissure Eruptions – associated with mid-ocean ridges and rift valleys, e.g., Hawaii

- 2 *Draw labeled sketches of each type of eruption.*

Source: Clark, I.F. and Cook, B.J. (1986). *Perspectives of the Earth*. Australian Academy of Science:

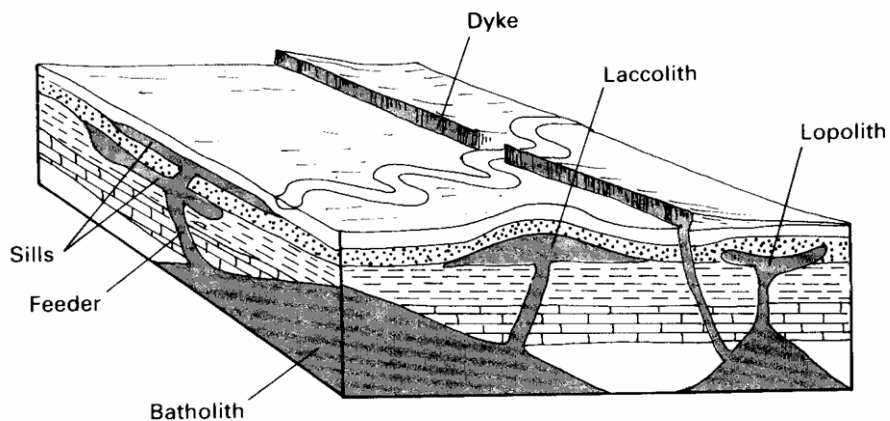


Canberra. p. 139.

- 3 Draw a series of sketches to describe what caused the massive explosion of Krakatau.

See Readings on Krakatau and answers to Exercise 3.1.

- 4 Illustrate the following igneous structures: batholith; sill; dyke; neck; laccolith; lava plateau.



Source: Clark, I.F. and Cook, B.J. (1986). *Perspectives of the Earth*. Australian Academy of Science: Canberra. p. 146.

- 5 *Describe with reference to plate tectonics the origins of volcanoes.*

See Activities 1.2 and 3.1

- 6 *Predict, from your knowledge of the previous geological history of the PNG islands, the types of eruptions that could be expected.*

PNG would expect mostly Central-type eruptions, that is, volcanoes with a central vent. However in some parts of the oceans at divergent plate boundaries there are fissure eruptions on the ocean floor. Past examples of fissure eruptions include the Manus Island group and the Marshall Bennett Islands that lie near divergent plate boundaries.

- 7 *Describe what steps people should take to escape the gases and ash of an erupting volcano.*

Recognise the hazard. Solid fallout may include pumice, red-hot rocks, ash and even pyroclastics. Gases will include carbon dioxide, sulfur dioxide and steam.

Action: Little can be done to escape a pyroclastic flow that is heading your way! If large fragments and hot material is falling stay under solid cover. You can be killed or injured by falling stones. If there is only ash, again stay under cover unless it is light enough to see where you are going.

Always assume that there are poisonous (sulfur dioxide) and suffocating (carbon dioxide) gases during an eruption. Cover your mouth and nose with a moistened cloth and tie it around your head. Proceed to the nearest high point away from the eruption. If you can determine the direction of the wind head diagonally across the wind is possible as this may take you out of the ash and gas fall more quickly.

Emergency supplies: Every household should have a battery radio, a torch, a set of fresh batteries, drinking water, cloth for dust/gas protection and substantial footwear.

E6 Earth in space

Rationale

This module contributes to the study of Environmental Science. This is a core module for the Unit *Environmental Science*. Module E6 *Earth in Space* provides in-depth treatment of topics listed in the Primary Environmental Science Syllabuses for Lower and Upper Primary.

Much prehistory and cultural traditions are associated with observations of the motion of celestial bodies and the stars. Some coastal Papuan new Guinea cultures have strong associations with the constellations using these to navigate across oceans and seas. Through a study of astronomy teachers are better able to relate to these ancient traditional uses of astronomy.

Objectives

At the end of this module students should be able to:

- identify your own prior knowledge about the changing sky
- find cardinal directions using the sun or stars
- identify some major stars and constellations
- use star charts and models to observe changes in the night sky
- predict the movement of star patterns
- observe and record the changing shape and position of the moon
- recognise the phases of the moon
- predict changes to moon phases and the changing position of the moon
- observe and predict the movement and the position of the sun and planets
- be persistent and systematic in collecting data
- sketch observations accurately
- interpret tables of data
- create pictorial representations
- report on observations in an informed manner

Main ideas developed

Our Earth is part of a planetary system including the Moon and the Sun;

Measurement of the positions of celestial objects may be made using references to the Earth coordinates.

Direction may be found using knowledge of celestial navigation.

Careful observation of the movement of stars, planets and the Sun provides evidence for the relationships between the bodies within the solar system and space.

The tilt of the Earth's axis and the annual revolution of the Earth around the Sun causes seasons.

Alignment of the Moon and Sun may cause lunar and solar eclipses.

Content and sequencing

Prior beliefs

- Investigating own prior knowledge about astronomical phenomena

The Changing Stars

- Use coordinates to find direction and record observations;
- North; altitude and azimuth;
- Recognising stars and constellations;
- Observing the night sky; star patterns and movement; finding South

Recognising stars and constellations

- Star Patterns
- Star Movement
- Finding South
- Observing the night sky

The Changing Moon

- Observing phases of the Moon
- Drawing Phases of the Moon
- Recording Phases of the Moon
- Movement of Sun, Earth and Moon
- Model of Sun-Earth-Moon

Our star - the Sun!

- Projecting the sun's image; movement of the Sun and seasons; eclipses.
- Projecting the sun's image
- Movement of the Sun and seasons
- Keeping time
- Modelling eclipses

Our planets

- Famous astronomers
- Observing the planets
- Conjunctions

Suggested teaching strategies

This module should be delivered through the use of support materials, a lecture program, laboratory and field-based activities and a workshop/tutorial program.

The practical component is strongly based on the application of observation and recording skills. Field studies should be an integral part of the teaching program. Activities provide a hands-on approach to the teaching of this module.

Throughout the teaching of this module there should be a strong emphasis on the constructivist approach to learning which can be readily applied to science teaching in the classroom. This will ensure that students have a thorough grounding and understanding of the concepts. Students will be encouraged to apply their new knowledge and skills to the context of teaching at different levels in primary schools.

For more about the constructivist approach see the Science teaching methods unit: *Teaching Constructively in Science*.

This module should be assessed in a way that provides students with the opportunity to demonstrate their ability to observe and record methodically as well as their knowledge of the application of concepts.

Prior beliefs

Interview a local person about their understanding (beliefs) of the universe and the objects in space.

Find out how astronomy has been used for everyday activities in the past or present. For example, how was astronomy linked to gardening, fishing and hunting?

Conduct a case study on local astronomical beliefs. Share the findings with students and use these as a discussion starter.

Students should be encouraged to challenge their own beliefs and knowledge about the universe.

The Changing Stars

The use of suitable videos and viewing nights is essential if students are to acquire a basic understanding of the way stars and constellations appear to move through the sky, day and night!

There will be more success in learning if practical activities are used from the outset. Students must be convinced that they should “discover” for themselves in order to understand the concepts.

Many students and lecturers alike will better understand the concepts through an observation first approach.

The activities presented in the student materials provide an excellent opportunity for students to become disciplined in observing, recording and reporting accurately in a science!

Recognising stars and constellations

Once again, an observational, discovery approach is recommended for this topic.

How does the lecturer become acquainted with the patterns of stars and the major stars?

The Earth Centered Universe

An excellent Shareware program has been included in the Resources Folder on the Science CD ROM. (Colleges are encouraged to Register and obtain the full version. Details are given in the Resources list earlier in this Guide). This software will generate accurate star charts based on the horizon and time for the locality in which you live.

Detailed instructions are given in the Help files in the program. Here are instructions some to get you started after installing the program:

From the menu <SET> go to <Time> and enter the local time.

From the menu <SET> go to <Geographic location> and enter the local latitude and longitude. Both must be entered as negative numbers (South and West). Enter “-10” for the time zone in PNG (10 hours ahead of Universal Time - UTC).

From the menu <FIELD> go to <Chart Mode> select local horizon.

Use the menu <CENTER ON> to select the view required.

Centring on the different cardinal points of the horizon (E, S, W and N) will give a set of star charts that can be used from your local position. You can also centre on various celestial objects such as the Moon to track its position over a number of days (use the little walking person button to advance time).

The Changing Moon

Once again it is important that students observe the changes to the Moon first hand over the period of one lunar month. Observations also provide students with an opportunity to sketch what they see accurately.

The lecturer should also draw on the cultural significance of the moon and the ways both Melanesian and Polynesian cultures used the path and phases of the Moon in the past.

For example, those who fish know that the best fishing occurs near the full moon. The tides are also greater during Full or New Moon. These experiences can be related to the scientific explanations and will then be more meaningful.

The emphasis should be on the collection and reporting of observations rather than remembering facts about the Moon.

Our star - the Sun!

The following notes may assist the lecturer with the topic about the Sun. (Source J. Broadfoot, QUT)

Sun's composition and structure

Our Sun (Sol) is an average star in luminosity, size and mass.

- Mass 333 400 x Earth
- Density 1.41g/cm³
- Spectral Class G2V
- Magnitude – 26.7
- Absolute magnitude + 4.8
- Rotation Period 24 d 16 hr

Sun's atmosphere has three regions:

1. Photosphere
2. Chromosphere
3. Corona (outer)

1. *Photosphere*

Limit of visibility through the sun's atmosphere

- limb darkening gives grazing view of edge and information on temperature, density and pressure of gases in the photosphere
- about 500 km deep
- 3400 times thinner than Earth's atmosphere
- temperature is 4500 → 6800K
- gases of higher layers produce absorption spectra
- Solar spectrum identifies 60 elements and 18 molecules (in the sunspots)
- 3/4 of mass is hydrogen
- 98% is hydrogen and helium - 2% other elements
- granulations (convection cells)

2. *Chromosphere (2000 - 3000 km)*

- studied during total solar eclipses
- 10000 km deep
- temperature from 10000 to 500 000 K at upper levels
- spectrum during eclipse of sun led to the discovery of helium gas in 1895
- pink due to emission lines of hydrogen
- filtergrams reveal detail of upper chromosphere including spicules

- spicules are jets on the outer edge of the chromosphere (100 to 1000 km diameter and about 10000K (cooler))
- spicules governed by strong magnetic fields

3. *Corona (12+ solar radii into space)*

- studied during total solar eclipses
- spectrum shows reflected light from dust and scattered light from free electrons
- 500000 to 2000000K in temperature
- density 1 to 10 atoms per cm^3 (no black body radiation)
- solar winds 300 to 800 km/s - protons and electrons

Some features and properties of the sun

Rotation

- doppler effect shows movement about an axis - 25 days at the equator
- differential rotation (slower) seen at about 30° (indicates fluid nature of Sun)
- W to E rotation
- produces magnetic field

Granulation

- convection current cells move at 2-3 km/s
- hot and "cold" gas observed
- each granule about 1000 km across

Super Granulation

- clusters of granules about 30 000 km in diameter
- rhythmic pulse observed (5 minute oscillation)

Sunspots

- about 1500 K 'cooler' and gives contrast (actually orange-red)
- dark central area called umbra (4240 K) and less dark area is penumbra
- sunspot cycles - 11.1 yrs - minimums and maximums for activity
- Zeeman effect - very strong magnetic fields (1000 times average for sun)

Above Photosphere

- observed and photographed using monochromatic filters
- **plages** are bright areas around sunspots due to highly excited ions
- **faculae** (little torches - plages)
- spicules - vertical jets at 30 km/s rise 5000 - 20 000 km

Prominences

- rise into corona up to 500000 km above photosphere
- can be quiescent / active / eruptive and travel at 700 km/s
- Surge prominences can rise at 1300 km/s
- loop prominence (hottest)

Flares

- areas of complex magnetic field structure
- last a few minutes and decay in an hour or so
- Chromospheric emission lines (H + Ca) brighten up to a high intensity some are 10 000 km wide
- most occur near sunspot maximums
- energy released from a flare over 1/1000 of sun's surface can outshine sun in UV, X rays and γ rays emitted
- material thrown into corona - expands and cools, as ions and electrons recombine
- do not know energy source of flares or mechanisms
- disturb earth's magnetic field - affect communications and cause auroras

Babcock theory of solar activity

The solar magnetic field is about the intensity of that of earth. The magnetic field in photosphere follows motion of gases in photosphere but sun rotates differentially causing field lines to wind up thus producing strong local magnetic fields. Matter tries to expand and lower the magnetic field strength and as it does the matter rises. Rising currents carry field lines into loops above it. Sunspots occur where field cables intersect the photosphere and expanding gases in these regions cool and darken. Field lines eventually coalesce and disperse due to continuing rotation.

Solar wind

Charged particles, ions, gases (mostly hydrogen) and radiation move away from sun through solar system at up to 1000 km/sec near earth (2-10 ions/cm). Sunspot activities produce magnetic storms on earth which upset short wave radio and cause auroras due to high levels of X ray and UV radiation. Disruption to the earth's ionosphere causes "fadeouts" in communications. Changes to earth's climate have been hypothesised as being caused by solar winds.

Our planets

These notes should be used by lecturers as a guide to assist students with the construction of models. This is one of the best ways to demonstrate scale and size to students. **See note in student activities.**

MERCURY

- Mass is 1/18 earth; Diameter: 4878 km; Density = 5.4 g.cm^{-3} ; Iron core
- Distance from Sun – 58 million km
- Period of rotation is 59 days.
- Phases like the moon
- Atmosphere of hydrogen at very low gas pressure
- Weak magnetic field suggests a solid core
- Craters and basins to 1300km
- Evidence of lava flows

VENUS

- Diameter - 12 100 km; distance from Sun – 108 mkm;
- Period of rotation – 243 days
- Surface temperature is 700K
- Upper atmosphere is highly refractive due to atmosphere of sulfuric acid, sulfur dioxide and sulfur (60km to 12km H_2SO_4 ; 4 to 5km S (l) and (s))
- Chemical activity in the atmosphere produces lightning
- Winds of 100 - 200 km/hr and clear poles due to convection
- Atmosphere is approximately 96% CO_2 , 3.4% N_2 , 0.6% oxygen
- Greenhouse effect due to atmosphere
- Surface is dry and dusty; 80% is fairly smooth;
- 11km high mountain (Maxwell); rift valleys and craters; tectonic activity limited

EARTH

- Diameter – 12 760 km; distance from Sun – 150 mkm (also called an Astronomical Unit - AU)
- Period of rotation – 23 hr 56 min
- Satellites – One - “Moon”

MARS

- Diameter – 6794 km; distance from Sun – 228 mkm
- Period of rotation – 24 hr 37 min

Atmosphere

- To 45km - Ice and CO_2
- 95% CO_2 ; 2-3% N_2 ; 1-2% Ar
- Pressure = 1/10 Earth's atmospheric pressure
- Argon indicates atmospheric pressure was once higher

Surface

- Temperatures Equator 30°C at noon; – 75°C at midnight; Poles – 15°C

Exploration

Mariner 4 (1965) - 22 photos; Mariner 6 and 7 (1969) - 200 photos; Mariner 9 (1971) - 7329 photos; Viking 1 and 2 Landers (1976) (no life, gas exchange experiments, seismic activity, absorption experiments)

Satellites

- Phobos (28-20km) revolves in 7 hr 39 min (less than Mars day therefore rises in W and sets in E); large crater "Stickney"
- Demos (12-16km) revolves in 30 hr 18 mins

Seasons Ice caps (some CO₂) (sufficient to cover planet with 1 metre water)

Volcanism 12 volcanoes; largest is **Olympus Mons** 25km high, 600 km wide

Canyons, Rifts Valles Marineris 5000km long, 75 km wide and 6 km deep

No plate tectonics therefore no migrating **hot spot**

Dry river beds indicate that water may be as permafrost or lost from atmosphere (low pressure)

JUPITER

- Mass is 318 times that of earth; diameter is 143 900 km (11 times earth); distance from sun is 778 mkm (5.2 AU)
- Composition 98% H₂ and He in ratio 3:1 (similar to the Sun) compressed to solid and metallic states; some methane and ammonia in outer atmosphere.
- Size: Jupiter has maximum size for a cold body of H₂ otherwise it would be a star!
Temp 200K. Radiates 2 1/2 times energy received (mainly infra red) (radioactivity, gravitational contractions, energy belts)

Exploration 1973,74 pioneer; VOYAGER 1 and 2 - 33 000 photos

Rotations 10 hrs - clouds show current flow

Red Spot Giant eddy 50 000km - 6 days rotation

Faint Ring At 260 000km: 6 000km wide; 30km thick; 8-10 micron particles

Magnetic Field Very strong 20-30 x earth - produces radio waves, etc.

Satellites	16	OUTER	eccentric revolution E -> W
		MIDDLE	eccentric E -> W rev
		INNER (6)	visual W->E (circular orbits)

V Amalthea (radius 70 km); orbital radius 360 000km; orbital period = 0.498 days

I Io (R = 1820km); orbital radius 840 000km; orbital period = 1.769 days; volcanic - 1mm/yr sulfur - molten core - gravity

II Europa (1525km); (1.3 mkm); (3.551 days); less craters, more cracks

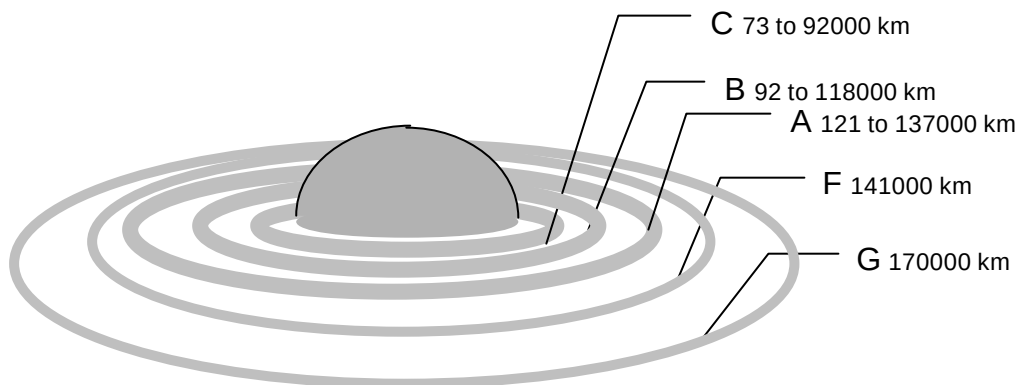
III Ganymede (2635km); (2.1 mkm); (7.155 days); very cratered

IV Callisto (2450km); (3.8 mkm); (16.69 days); 50% ice and cracked

SATURN

- 92 times earth's mass; diameter of 120 500 km; Distance from Sun – 1427 mkm (9.54 AU); Density = 0.7 g/cm^3 ; composition of H_2 and He
- structure similar to Jupiter
- emits more energy than it receives (IR)
- rotates in 10 hours
- slow rotation near poles indicates gaseous composition
- oblate (10%)
- 27° inclination of axis - tilted rings; outer layers - Pioneer II - hazy
- winds 300 miles/hr
- spots like Jupiter - up to 100km
- ammonia ice clouds - outer.
- magnetosphere

Rings of Saturn



Cassini's division (between A and B); Mimas' period is 2 times this division. Particles in this zone are near Mimas which perturbs particles. This is known as the resonance effect. Tidal forces would break up a satellite in the gaps.

Two shepherding satellites between A-F, F-G were discovered by Voyager.

Particles are mostly water, ice and micro dust. Some in brighter sections are ice. Dark spokes move through rings due to electrical activity and action of UV on methane → carbon.

Satellites 24 confirmed; 100 - 1530km; 1.4 g/cm^3 ; Most heavily cratered; water-ice surface

Titan is planet sized (diameter 2 900km); (solid radius 2575km); 98% N_2 , 2% CH_4 ; temperature 97K - opaque clouds

Iapetus bright and dust covered

Dione 4th largest; fractures

Mimas eye like crater

Enceladus highly reflective, large smooth crust

URANUS

- Discovered by Herschel 1871
- Diameter 51 100km; very slow motion
- Distance from Sun - 2870 mkm;
- Period of rotation is 17 hr 4 min (measured by doppler shift)
- Angular diameter is 4 seconds;
- Five main satellites (130000 - 587000 km from planet) and shepherds; 15 satellites
- Ring system (9 small) Voyager 1986. Thin dark CH₄ ring at 102000km; not continuous
- Composition - H₂ and He; some methane (green)
- Inclination - 82° and rotates in reverse
- Winds 300km/hr; magnetic field with radiation belts like earth

NEPTUNE

- Predicted mathematically; Diameter 50 500 km; Distance is 4497 mkm (30 AU)
- Mass 17.2 times earth; Density 1.5g/cm³; Orbital velocity 5.4km/s
- Rotates in 15 to 20 hours; Temp 40K (based on IR); Subtends 2 secs; occultations give diameter
- Satellites (2) Triton - (355 000km) E to W orbit
Nereid - eccentric (1.4 - 9.7 mkm)
- Colour is greenish; CH₄ and H₂ (He?)
- Discovered? 1613 as 8th magnitude star by Galileo during conjunction with Jupiter - discrepancy in calculated position; Voyager 1989

PLUTO

- Diameter 2445 km; temperature 40K; Distance from Sun - 5 900 million km (39.4 AU)
- Rotation period 6.4 days
- 1930 - photographed using Blink Microscope; mathematically predicted by Lovell (He died before discovery)
- Aphelion 7 000mkm; perihelion closer to Neptune
- Satellite - Charon is 1/2 diam of Pluto; mass is 0.0022 times earth.

Suggested student activities

The activities listed in the Module have been carefully compiled to provide an observational and discovery approach to the acquisition of astronomical concepts. Students should be encouraged to observe and record on a regular and methodical basis, just like the famous astronomers of the past. It is also a good idea to integrate existing beliefs from pre-colonisation times.

Students are generally quite naive in their perceptions of space and astronomical phenomena. A well-planned series of observations of objects of interest is essential for students to overcome their misconceptions or pre-existing notions. Only after the

opportunity to observe first hand should students be introduced to the concepts of space and motion. Regular observations of stars and planets as well as the sun and moon will greatly assist students in understanding the concepts.

Modelling is also essential for students to comprehend the motions and relationships between the members of the solar system. The size and position of planets can be modelled using a suitable scale (different for diameter of planets and distance from the Sun). This is also a mathematics exercise!

The models can then be hung in and out of the classroom at the pre-calculated scale distances and information cards can be suspended with the round cut outs of the planets.

Prior beliefs

Prior beliefs	Activity 1.1
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The Changing Stars

Finding North	Activity 2.1
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Determining altitude and azimuth	Activity 2.2
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Recognising stars and constellations

Star Patterns	Activity 3.1
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Star Movement	Activity 3.2
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Finding South	Activity 3.3
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Observing the night sky	Activity 3.4
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The Changing Moon

Drawing Phases of the Moon	Activity 4.1
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Recording Phases of the Moon	Activity 4.2
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Movement of Sun, Earth and Moon	Activity 4.3
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Model of Sun-Earth-Moon	Activity 4.4
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Our star - the Sun!

Projecting the sun's image	Activity 5.1
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Movement of the Sun	Activity 5.2
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Keeping time	Activity 5.3
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Modelling eclipses	Activity 5.4
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Our planets

Observing the planets	Activity 6.1
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Suggested scales for planetary display

The table could be completed by students and scales calculated beforehand.

Planet	Actual size Diam in km	Scale size mm	Actual distance from Sun in AU	Scale distance metres
Sun	1500000	15 000		
Mercury	4 900	49	0.39	0.39
Venus	12 100	121	0.72	0.72
Earth	12 750	127	1.00	1.00
Mars	6 800	68	1.52	1.52
Jupiter	143 900	1 439	5.20	5.20
Saturn	120 500	1 205	9.54	9.54
Uranus	51 100	511	19.18	19.18
Neptune	50 500	505	30.00	30.00
Pluto	2450	25	39.44	39.44

Obviously the classroom will only accommodate the scale for distances from the Sun as far as Saturn. After that markers will be needed to show that the other three planets are out in the grounds on the same scale.

For the larger planets old packing boxes or sections of cardboard should be used. For example Jupiter, the biggest, the cardboard will be 1.4 metres in diameter. A more permanent display can be made using old plywood.

To model the size of the sun simply cut a segment from a large piece of cardboard. You will not be able to make the whole circle!

An extra activity to improve estimation skills for astronomy

Estimating and Counting Stars

Objective: To introduce the students to the idea of estimation.

Materials: A game board/activity sheet; pencils for recording

Procedure:

- 1 *Form teams of four players*
- 2 *Have each team record their collective guess.*
- 3 *Have each team count the stars and record their answer.*
- 4 *Discuss the procedures used in estimating and counting by the various teams.*
- 5 *How many stars are there?*

Team Members:

Team Guess: _____

Team Count: _____

