Bharathidasan University

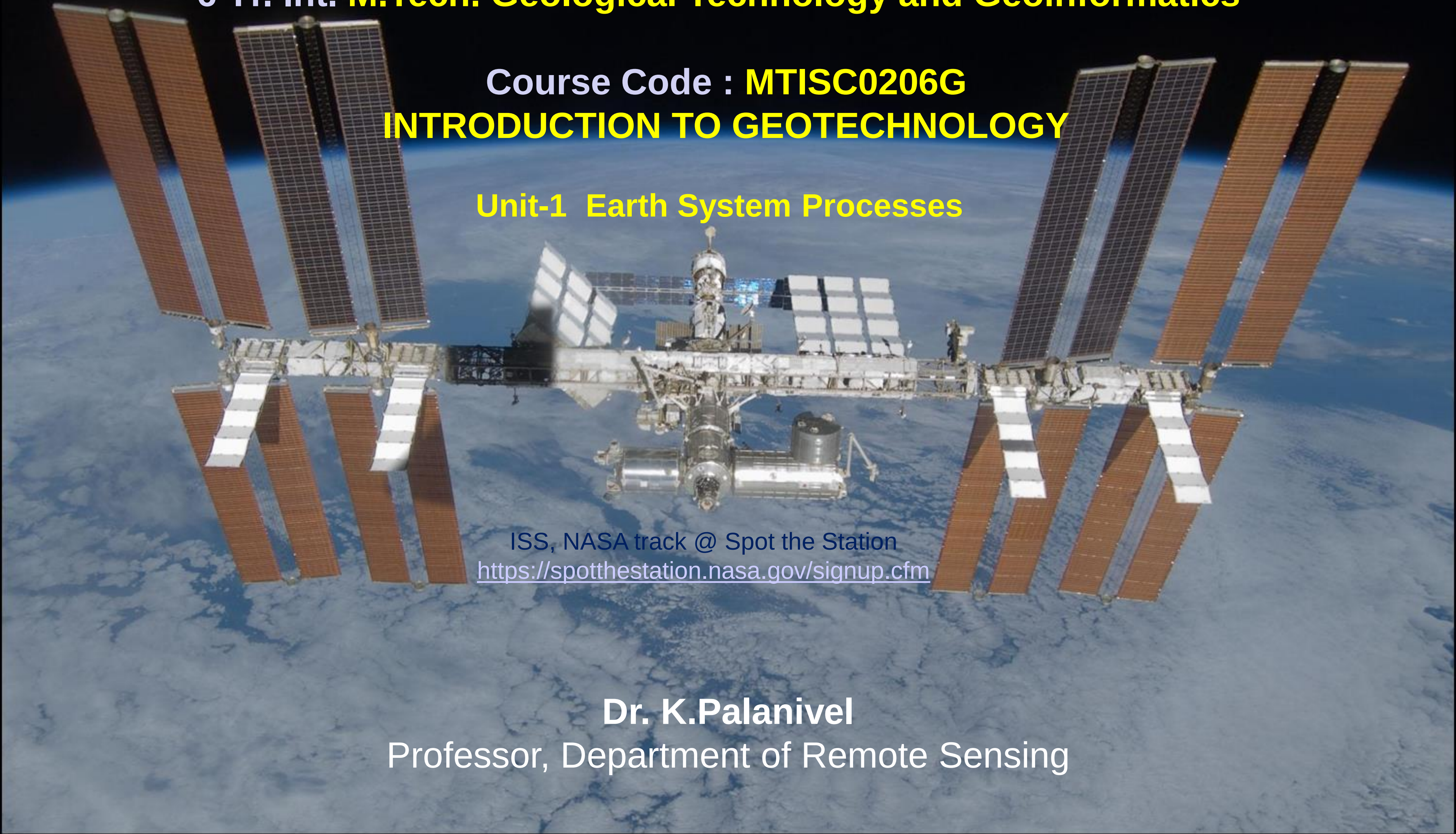
Tiruchirappalli – 620 023, Tamil Nadu

6 Yr. Int. M.Tech. Geological Technology and Geoinformatics

Course Code : MTISC0206G

INTRODUCTION TO GEOTECHNOLOGY

Unit-1 Earth System Processes



ISS, NASA track @ Spot the Station
https://spotthestation.nasa.gov/signup.cfm

Dr. K.Palanivel
Professor, Department of Remote Sensing

Course Objectives

- To know the content and familiarize the courses of this entire programme
- To study the basics and concepts of major disciplines in Geological Technology
- To understand the importance of Geoinformatics and its applications
- To learn the application of Geological Technology and Geoinformatics in natural resources mapping
- To learn the application of Geoinformatics in natural disaster mitigation.

MTISC-0206G - INTRODUCTION TO GEOTECHNOLOGY ---- 3 credits

1. Earth System Processes: 6hrs

Earth Sciences: Definition, Branches of Earth Sciences, Scope and importance of Earth Sciences

Earth System Processes: Origin, interior & age of the Earth – Plate tectonics – Formation of Continents & Oceans – Mountain building activities – origin of rivers – Physiography of the Earth.

2. Lithology, Structure, Geomorphology: 12hrs

Lithology: Rock forming minerals – Igneous, Sedimentary & Metamorphic Rocks – Stratigraphy.

Structure: Folds, faults, geotectonics and their significance.

Geomorphology: Various Geomorphic Processes – Regional Geomorphology of India – Geological Ecosystems.

3. Natural Resources and Disasters: 12hrs

Natural Resources: Mineral Provinces of India and exploration strategies – Hydrocarbon provinces of India and exploration strategies–Water Resources and exploration strategies. Soil, Forest & Biomass and Marine resources.

Natural Disasters: Geodynamic Processes and Natural Disasters (Seismicities – Landslides – Floods – Tsunami – Other Natural Disasters).

4. Remote Sensing Based Mapping: 12hrs

Aerial Remote Sensing – Satellite Remote Sensing Principles – Digital Image Processing concepts – GPS based mobile mapping principles – Image interpretation principles for Geotechnology.

5. Geoinformatics: 6hrs

Definition & Concepts – Input Sources (Satellite, Aerial & Ground based) - Computer based Geospatial data base generation – data modeling on Natural Resources, Eco Systems & Natural Disasters – Information Systems.

Course Outcomes

After the successful completion of this course, the students are able to:

- Create subject interest amongst the students joined in this programme and gain knowledge on variety of sub disciplines that they can choose for their future.
- Understand the scope and importance of the Geological Technology and Geoinformatics subjects.
- Provide a brief exposure to the course works of entire 6 year programme.
- Brief exposure to the advanced and computerized tools in Geoinformatics and their applications to Geology, Natural Resources and Natural Disasters.
- Understand the concepts of mapping using Remote Sensing Satellites, Aerial Photography and Digital Image Processing.
- Know the concepts of Geospatial / Geoinformatics Technology based database generation, modeling and information systems.

Text Books:

1. **Parbin Singh**,2008: A text book of Engineering & General Geology, S.K.Katarria & Sons, New Delhi.
2. **Mahapatra, G.B.**, 2007: A text book of Geology, CBS publishers & distributors, New Delhi.

References:

1. M.S. Krishnan, Geology of India & Burma, Higginbothams (P) Ltd., Chennai. 1968.
2. George Joseph, Fundamentals of Remote Sensing, 2nd Edition, Cambridge University Press. 2005.
3. Arthur Holmes, Principles of Physical geology, Thomas Nelson & Sons, USA 1964.
4. Gokkhale and Rao. Ore deposits of India, Thomson press, New Delhi, 1972.
5. Krishnaswamy, S. India's mineral resources, Oxford and IBH publishing, New Delhi. 1979.
6. Edwin H. Pascoe, A manual of the Geology of India and Burma, Controller of Publication, Govt. of India, New Delhi. 1973.
7. Sinha. R.K., A Treatise on Industrial Minerals of India, Allied Publishers Pvt. Ltd., Chennai, 1967.

8. Alfred Harker, Petrology for students, University Press, Cambridge.
9. Read, H.H. Rutley's Elements of Mineralogy, Thomas Murby & Co. London. 1947.
10. Alexander N.Winchell, Elements of Optical Mineralogy, Vol.I & II, Wiley Easter Pvt. Ltd., Publishers New Delhi. 1968.
11. Lillesand, T.M. and Kiefer, P.W, Remote Sensing and Image Interpretation, John Wiley & Sons, New York. 1986.
12. Burrough, P.A. Principles of Geographical Information Systems for Land Resources Assessment, Clarandone Press, Oxford. 1986.
13. Frank Press Raymond Siever: Understanding Earth (3rd ed). W.H. Freeman and Company. New York . 2000
14. B. J. Skinner and S.C. Porter: The Dynamic Earth – An Introduction to Physical Geology 3rd edition. John Wiley & Sons, New York. 1995
15. P. McL. D. Duff : Holme's Principles of Physical Geology (4th ed). Chapman & Hall, London. 1996.

UNIT-1

EARTH SYSTEM PROCESSES

Earth Sciences: Definition, Branches of Earth Sciences, Scope and importance of Earth Sciences.

Speed facts of our Mother Earth & related aspects:

(1) Self Rotational speed on the equator is approximately 1669.8 km/h. i.e. 1669.8/3600 sec. = **0.4638 km/sec.**

(2) Orbital revolution speed around the sun, once ever 365.2425 days is 107278.87 km/h i.e., **29.8 km/sec.**

(3) Velocity of our Milkyway Galaxy in space is 500 km/s & having a size of about 100 light years across.

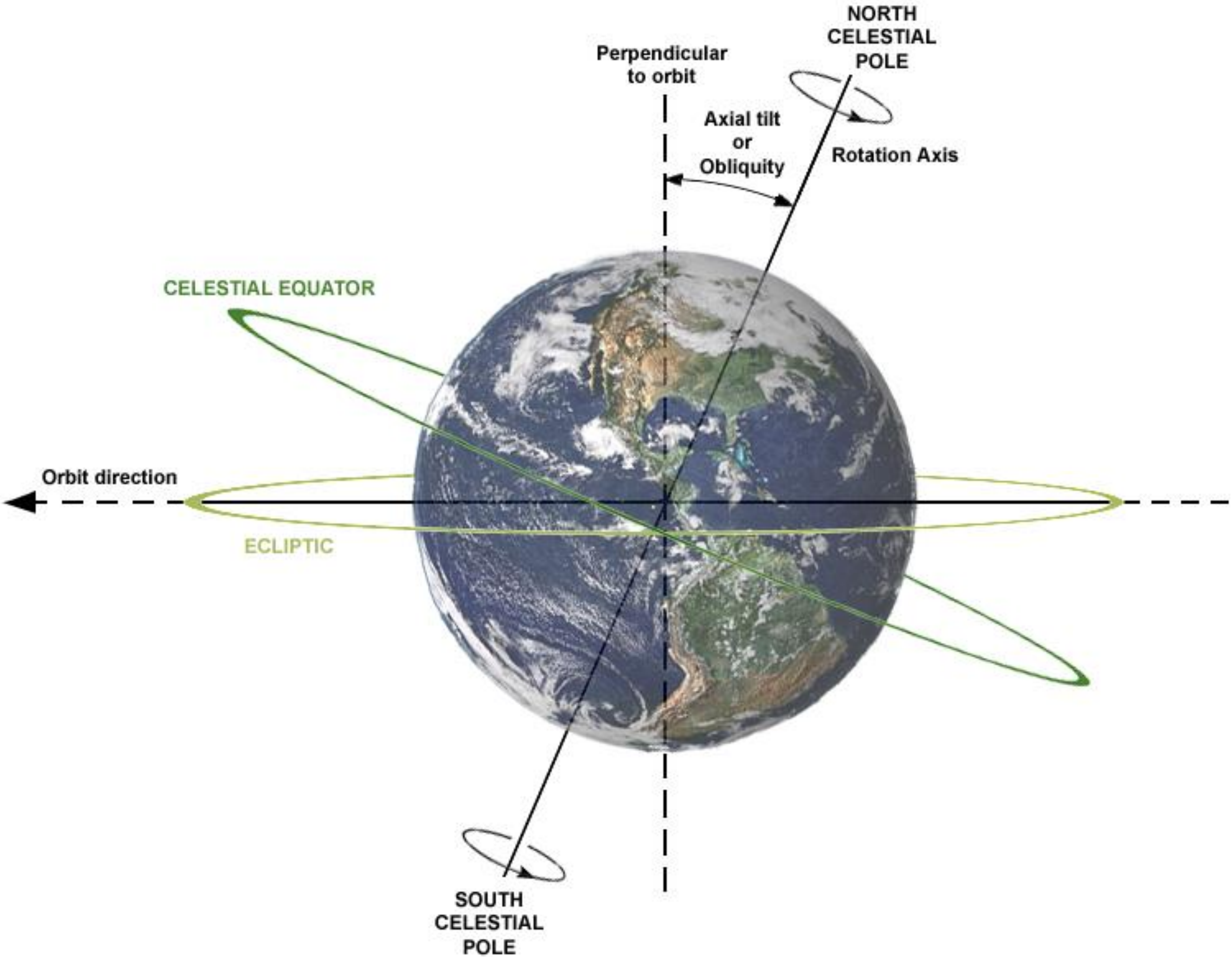
speed of light measured in vacuum is 2,99,792.458 kilometers per **second, i.e., approx. 3 lakh km/s**

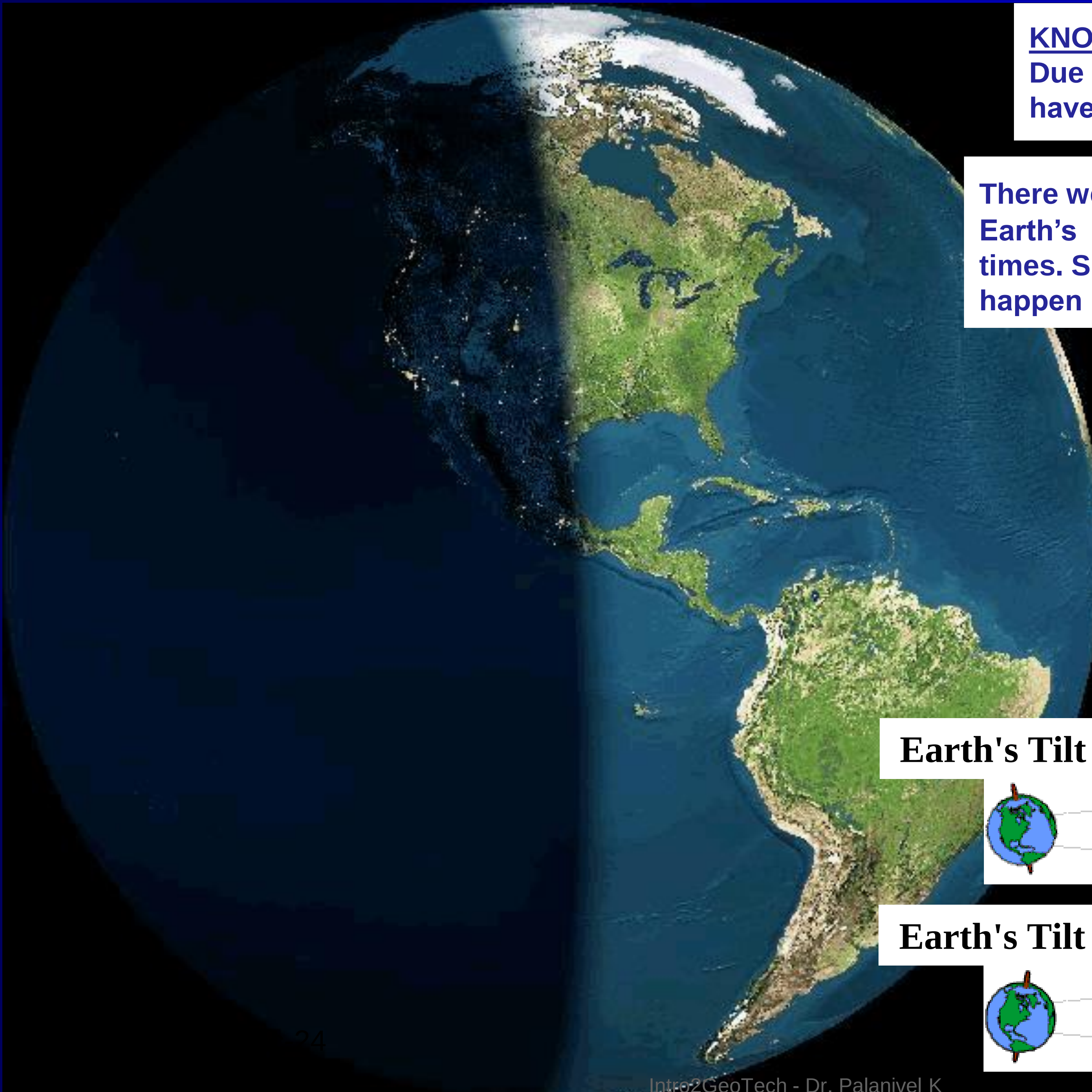
What is the radius of the Earth?
Equatorial = 6378 km
Polar = 6357 km.

What is the relative size - in terms of diameter - of the Sun with reference to the Earth?
109 times the diameter of the Earth.

What is an Astronomical Unit?
The mean distance between the Sun and the Earth is one AU, i.e., 150 Million Kilometers

What is the distance between the Moon and the Earth?
3,84,400 km


NORTH CELESTIAL POLE
Perpendicular to orbit
Axial tilt or Obliquity
Rotation Axis
CELESTIAL EQUATOR
Orbit direction
ECLIPTIC
SOUTH CELESTIAL POLE

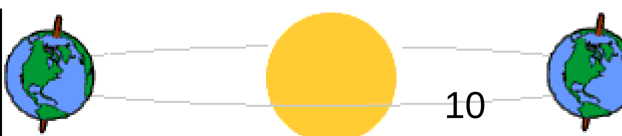


KNOWN FACT:
Due to the Axial Tilt (23.5º), we have different seasons…..

There were Wobblings of our Earth's axis during primitive times. Similar wobbling may also happen in future…

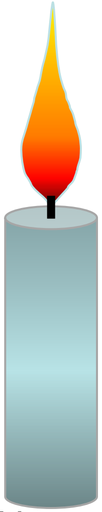
Earth's Tilt 13,000 years from Now

Earth's Tilt At Present Time (Now)



Homework:

1. What will be the self rotational speed of the objects on earth surface located at Poles, Tropics & the Equator?
2. What is the rate of movement of our Universe - in terms of ……km/s ?
3. Why the wavelengths of 1mm to 1m range are called microwaves though there are waves having very small wavelengths ranging in micro meter (μm) or even 1000 000 000 (1k lakh) times lesser , i.e., in nano meter (nm) size?
4. Why some watches are called as Quartz watches? What is the use of Quartz in them?
5. Why the sky and sea appears blue?
6. What would be the colour of space ?
7. What is the speed of International Space Station (ISS) – in km/s unit?
8. The shape of the candle flame in the Earth's surface is like a Thilaham. Do you know the shape of it in ISS?
9. Whether the continents are stable? What about our Indian sub-continent?
10. If yes/no, What is the reason, if no, how long it has moved & where from?



To understand the Earth System Processes, it is necessary to study …

EARTH SCIENCE

- DEFINITION
  - Any of the sciences that deals with the whole earth or it's part is called as EARTH SCIENCE.
  - It is also known as **Geoscience / Geology.**
  - The first and the foremost discipline of Earth Science is **Geology**.
  - Geology describes the rocky parts of the Earth's crust (or lithosphere – where the mineral and all other resources are occurring), interior, origin, formation of landforms that covers the surface and its historic development.

GEOTECHNOLOGY / GEOLOGICAL TECHNOLOGY - Definition

- The combined study of application of **Geoscientific** methods and **Geoengineering** techniques
- to the genuine sustainable exploitation and utilization of **Natural Geological Resources** (like mineral, water, hydrocarbon, geothermal resources, etc.) and mitigation, management planning and monitoring of **Natural Geological Disasters**
- by thorough understanding of **Earth system processes.**

Major subdisciplines of GEOLOGY

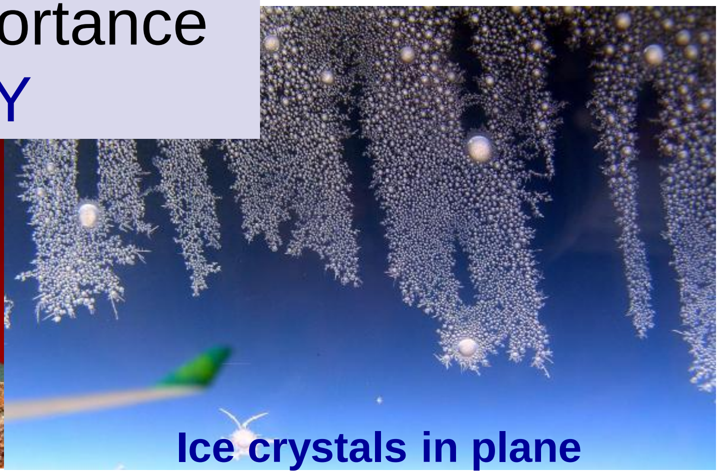
- Crystallography and Mineralogy
- Petrology,
- Geomorphology,
- Palaeontology,
- Stratigraphy,
- Structural geology,
- Geophysics,
- Geochemistry,
- Engineering geology and
- Fuel Geology

Definitions of Major Sub-disciplines, Importance and Further divisions in GEOLOGY

Crystallography

- is an experimental science of determining the arrangement of atoms in Crystal solids.

Azurite



Ice crystals in plane

Kyanite- Al_2SiO_5 **Triclinic**

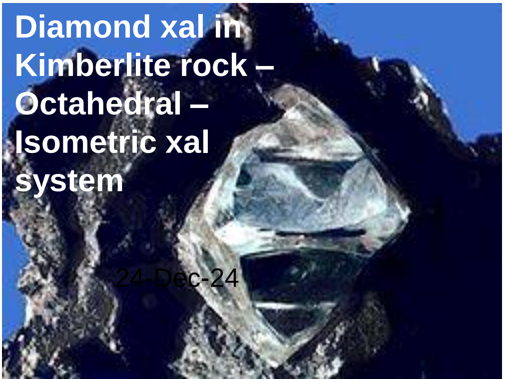
Kyanite - Used in refractory and ceramic products, including porcelain plumbing fixtures and dishware, electronics, electrical insulators and abrasives, as a semiprecious gemstone, also as one of the index minerals

Cluster of twinned Aragonite from Morocco –useful for sea life existence and maintains pH

Aragonite – Orthorhombic- $CaCO_3$

Quartz crystal is used as a most common **Crystal oscillator** in an electronic oscillator circuit that uses the mechanical resonance of a vibrating Quartz crystal to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time as in **Quartz wristwatches**, to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. →

Diamond



Diamond xal in Kimberlite rock – Octahedral – Isometric xal system

Beryl – Hexagonal

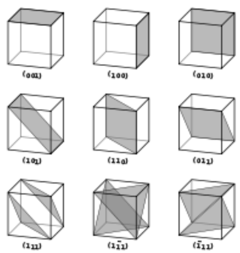
Quartz crystals

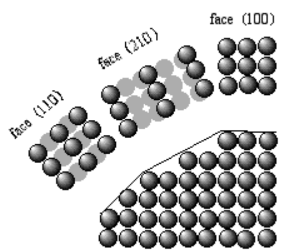
An eg. of closely packed lattice system

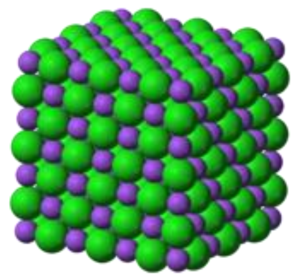
Physical Mineralogy

Physical mineralogy is a scientific study specifically focusing on the physical attributes of minerals to identify, classify, and categorize minerals.

Symmetry & Structures







Haematite – Brown streak

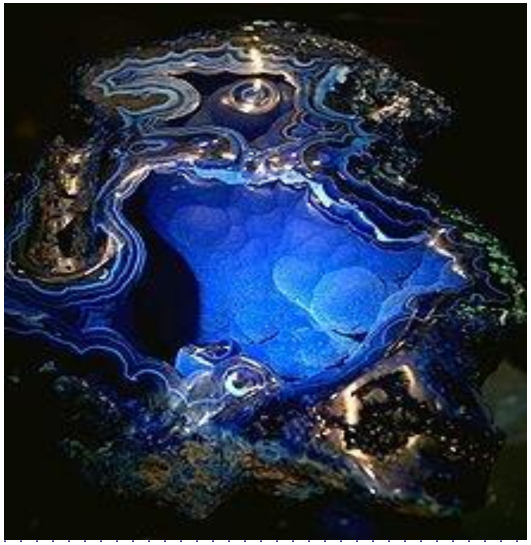
Garnet – Dodecahderal habit

Smithsonite – Botryoidal habit

Satinspar – Silky Lustre

Pyrite – Metallic Lustre

For e.g., Copper carbonate (CuCO3)



Azurite deposits on the interior surface of a geode

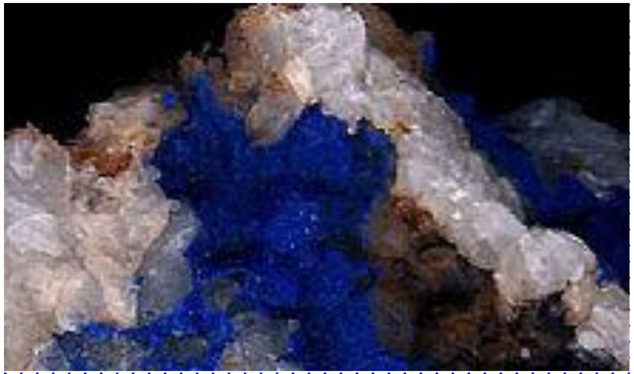
Economic Uses of Azurite – Blue paint - pigment, jewelry, Copper ore indicator

Azurite

Physical, Chemical and Optical Properties

General	
Category	Carbonate mineral
Formula (repeating unit)	$Cu_3(CO_3)_2(OH)_2$
Strunz classification	05.BA.05
Crystal symmetry	Monoclinic 2/m
Unit cell	a = 5.01 Å, b = 5.85 Å, c = 10.35 Å; β = 92.43°; Z=2
Identification	
Formula mass	344.67 g/mol
Color	Azure-blue, Berlin blue, very dark to pale blue; pale blue in transmitted light
Crystal habit	Massive, prismatic, stalactitic, tabular
Crystal system	Monoclinic Prismatic
Twinning	Rare, twin planes {101}, {102} or {001}
Cleavage	Perfect on {011}, fair on {100}, poor on {110}
Fracture	Conchoidal
Tenacity	brittle
Mohs scale hardness	3.5 to 4
Luster	Vitreous
Streak	Light Blue
Diaphaneity	Transparent to translucent
Specific gravity	3.773 (measured), 3.78 (calculated)
Optical properties	Biaxial (+)
Refractive index	$n_\alpha = 1.730$ $n_\beta = 1.758$ $n_\gamma = 1.838$
Birefringence	δ = 0.108
Pleochroism	Visible shades of blue
2V angle	Measured: 68°, calculated: 64°
Dispersion	relatively weak

Note: Hyperlinks of certain terms seen here are retained as such, so that you can get details for further understanding through ***internet*** connectivity**…**



Fresh, unweathered stalactitic azurite crystals showing the deep blue of unaltered azurite

It is a strong indicator mineral for the presence of copper ores – Malachite, Cuprite, etc. – 136 Cu mnls. exists in our Earth in total.

Petrology

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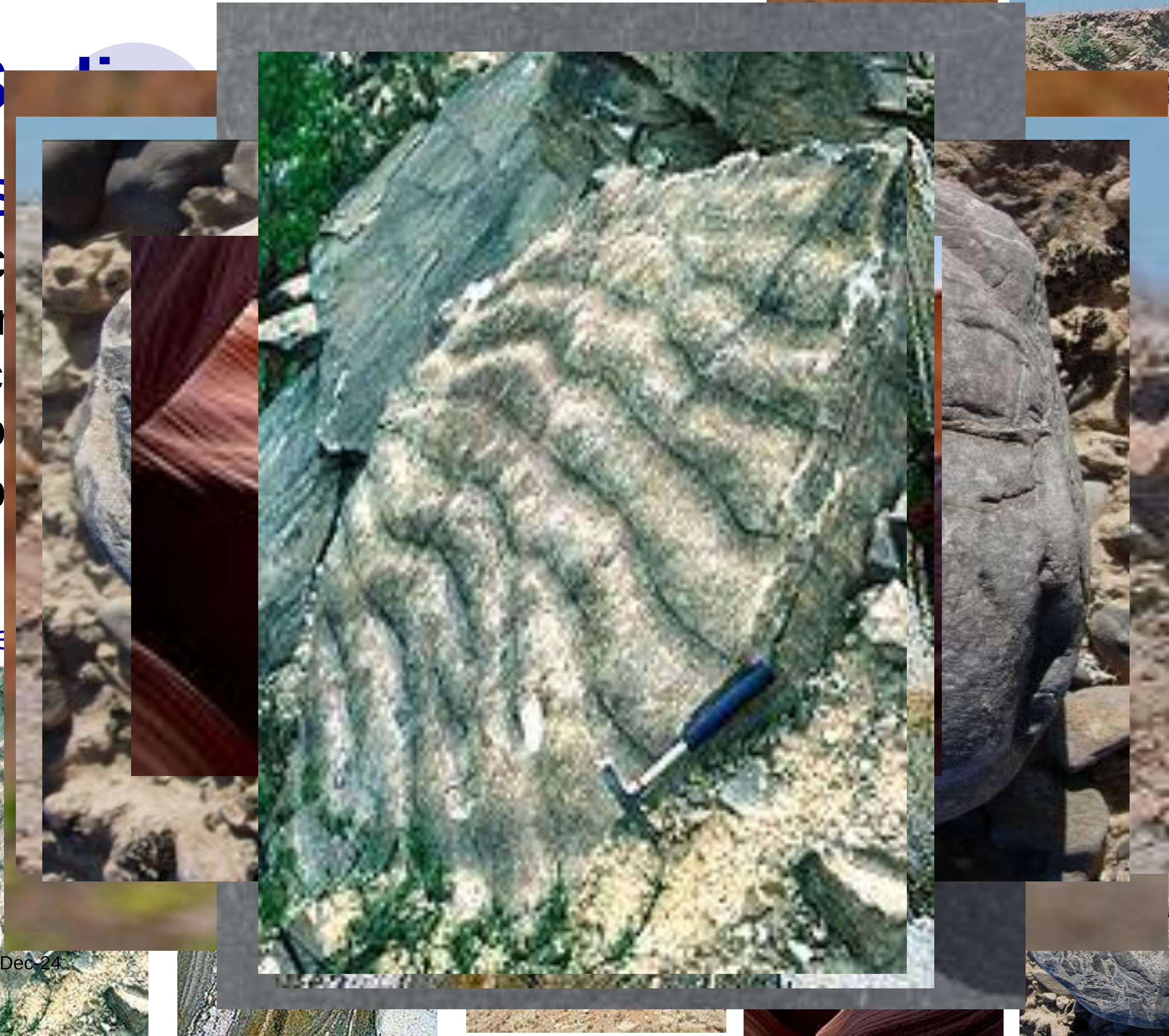

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Geophysics

- the quantitative observation of Earth's physical properties

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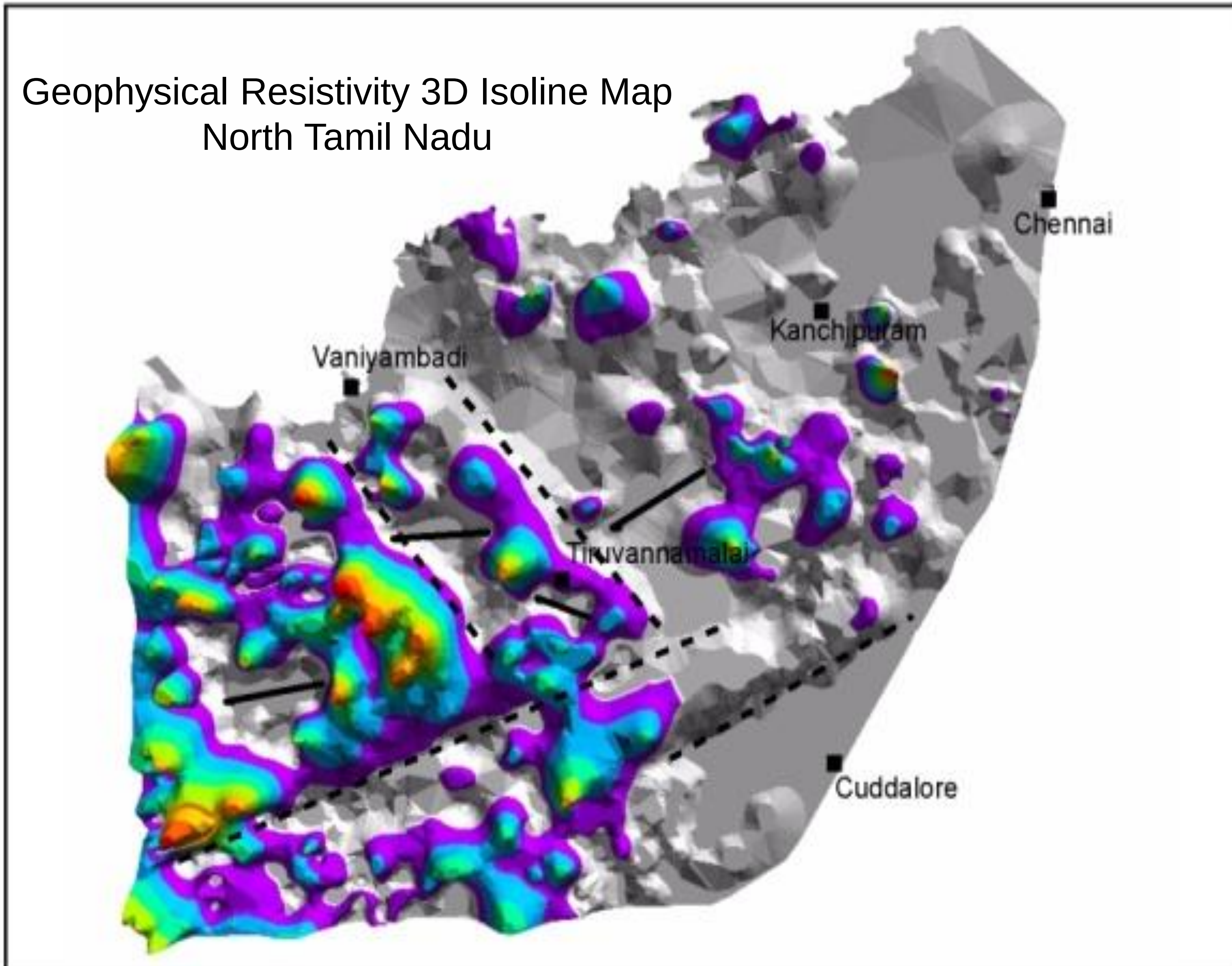
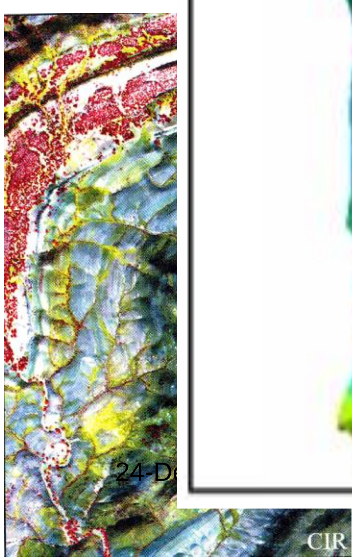




Magnesite-rich packages appear pale blue (arrowed) on the HyMap image

Geochemistry

- Study of chemical properties of rocks and sediments useful for resources exploration and hazard management
- study of the chemical composition of the Earth and other planets, chemical processes and reactions that govern the composition of rocks and soils, and the cycles of matter and energy that transport the Earth's chemical components in time and space, and their interaction with the hydrosphere and the atmosphere

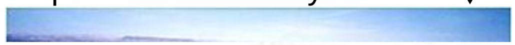
Isotope geochemistry: Determination of the relative and absolute concentrations of the elements and their isotopes in the earth and on earth's surface.
Examination of the distribution and movements of elements in different parts of the earth (crust, mantle, hydrosphere etc.) and in minerals with the goal to determine the underlying system of distribution and movement.
Cosmochemistry: Analysis of the distribution of elements and their isotopes in the cosmos.
Biogeochemistry: Field of study focusing on the effect of life on the chemistry of the earth.
Organic geochemistry: A study of the role of processes and compounds that are derived from living or once-living organisms.
Regional, environmental and exploration geochemistry: Applications to environmental, hydrological and mineral exploration studies.

Geomorphology

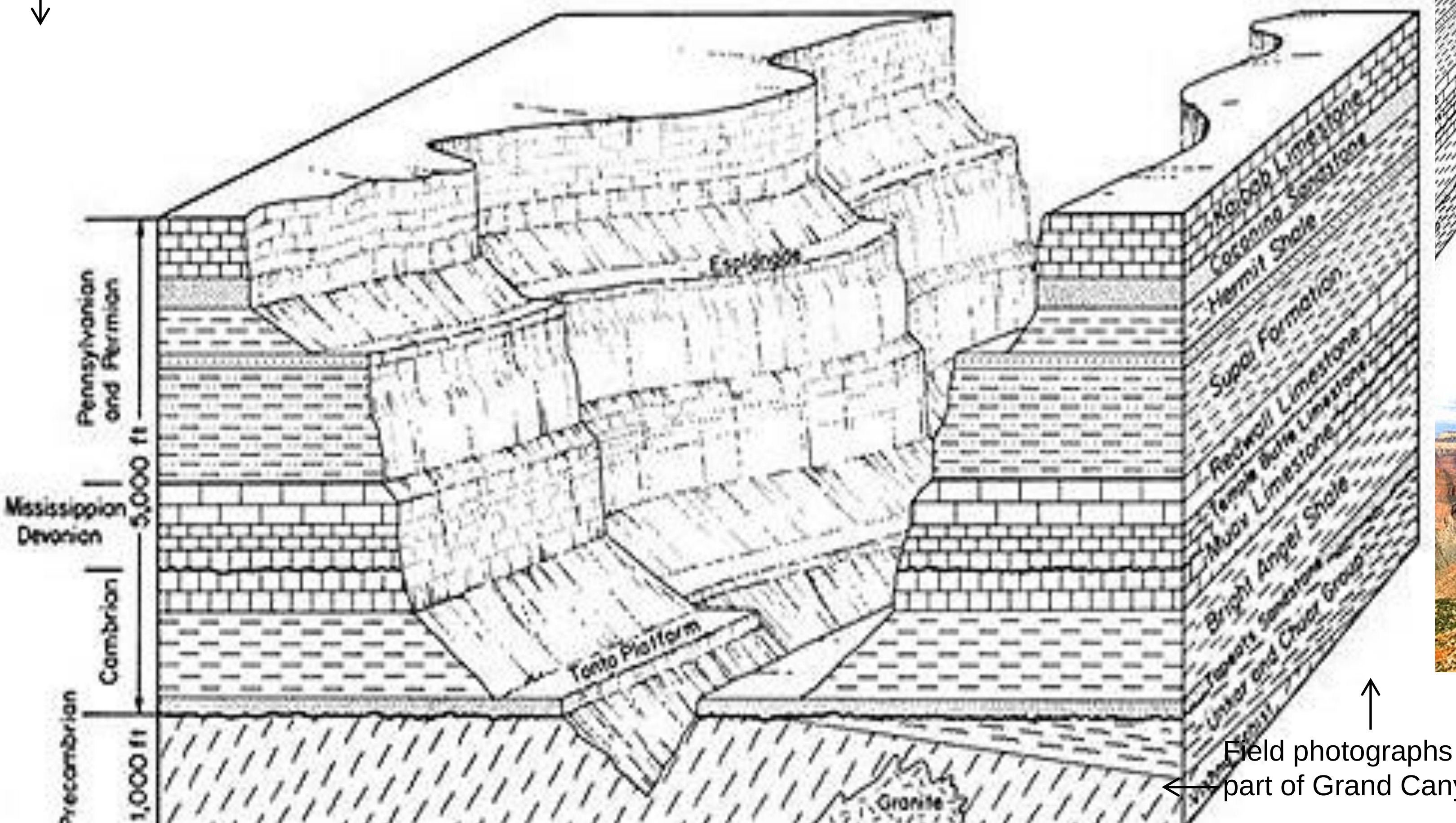
- **scientific study of landforms and the processes that shape them**

Satellite images of part of Grand Canyon

Colour Aerial photographs of part of Grand Canyon



Block Diagram of part of Grand Canyon



Field photographs of part of Grand Canyon

Fluvial, tectonic and denudational geomorphic processes in combination / intercalation have carved this formation and resulting into Canyon landscape.

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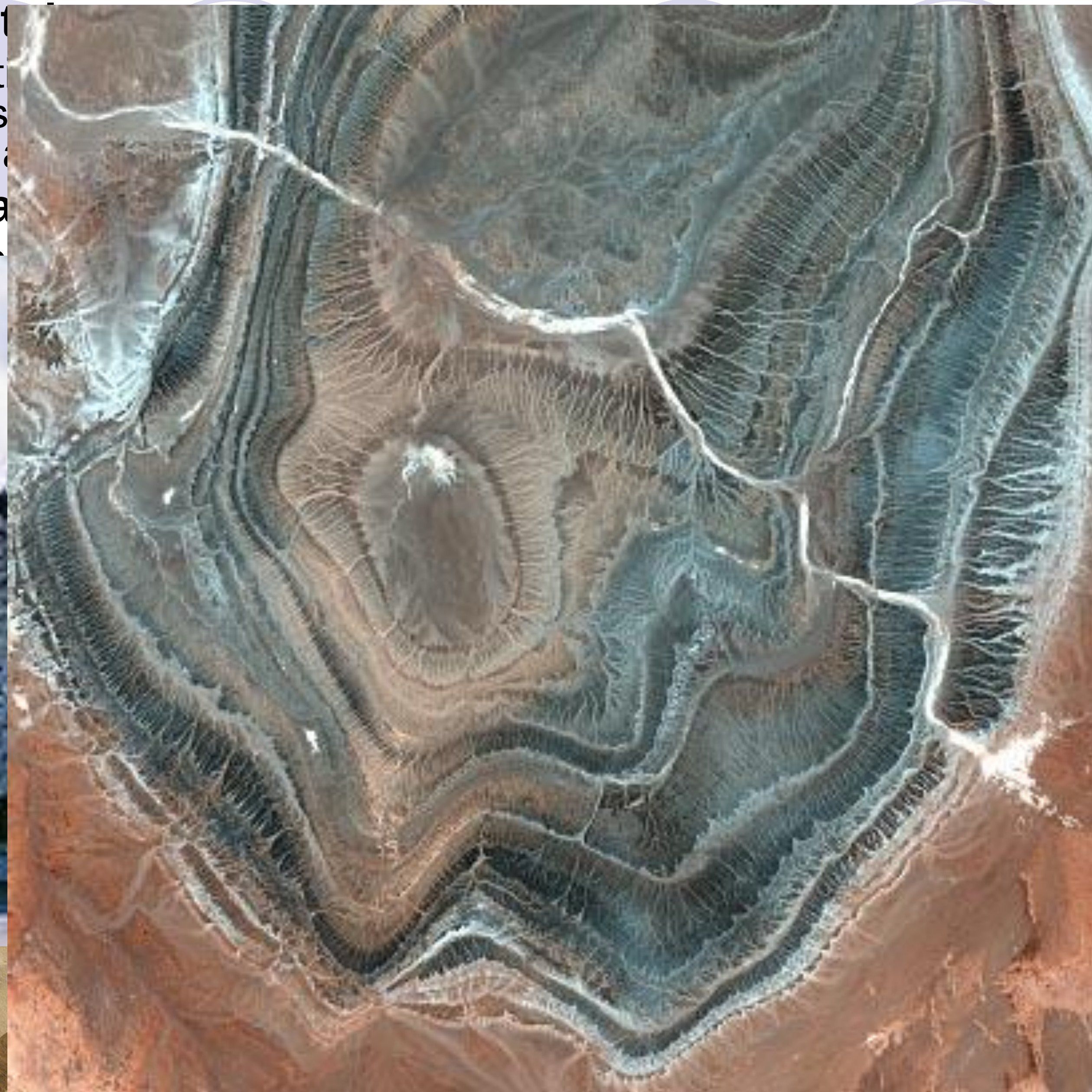
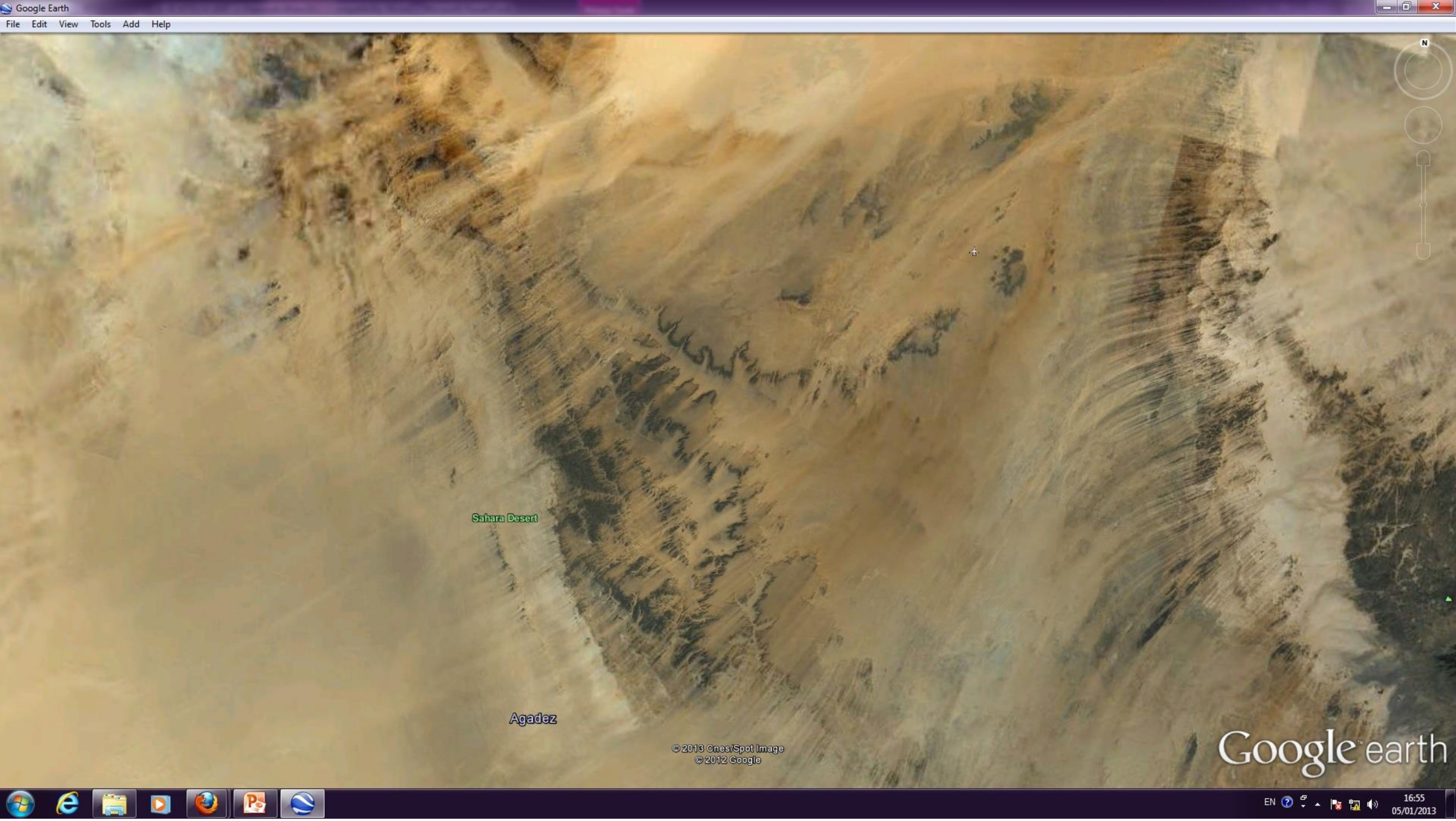
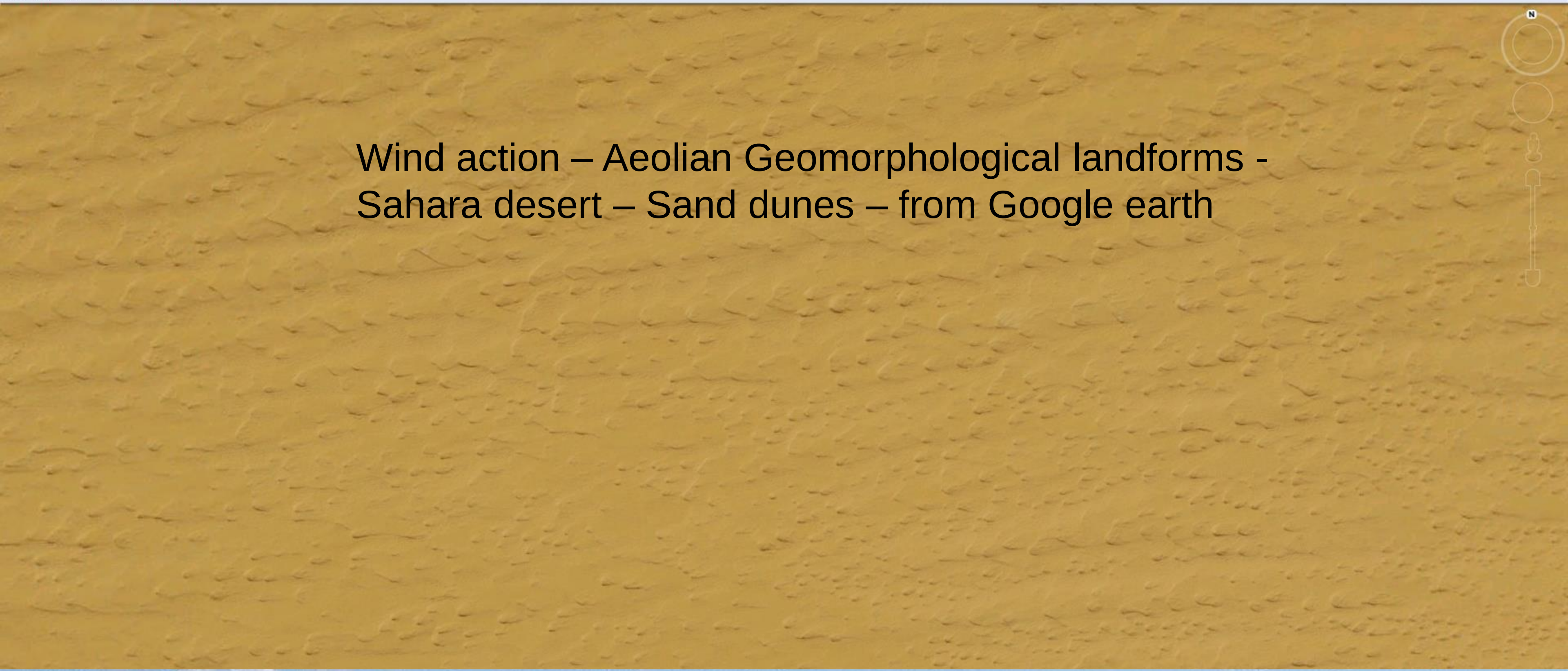
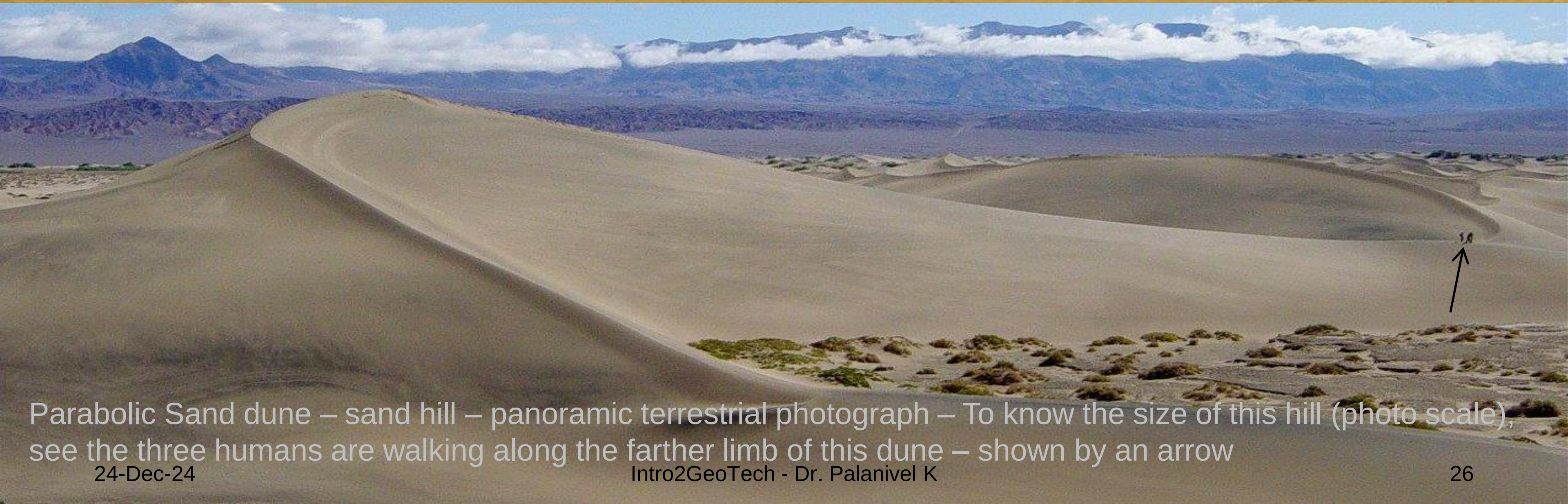




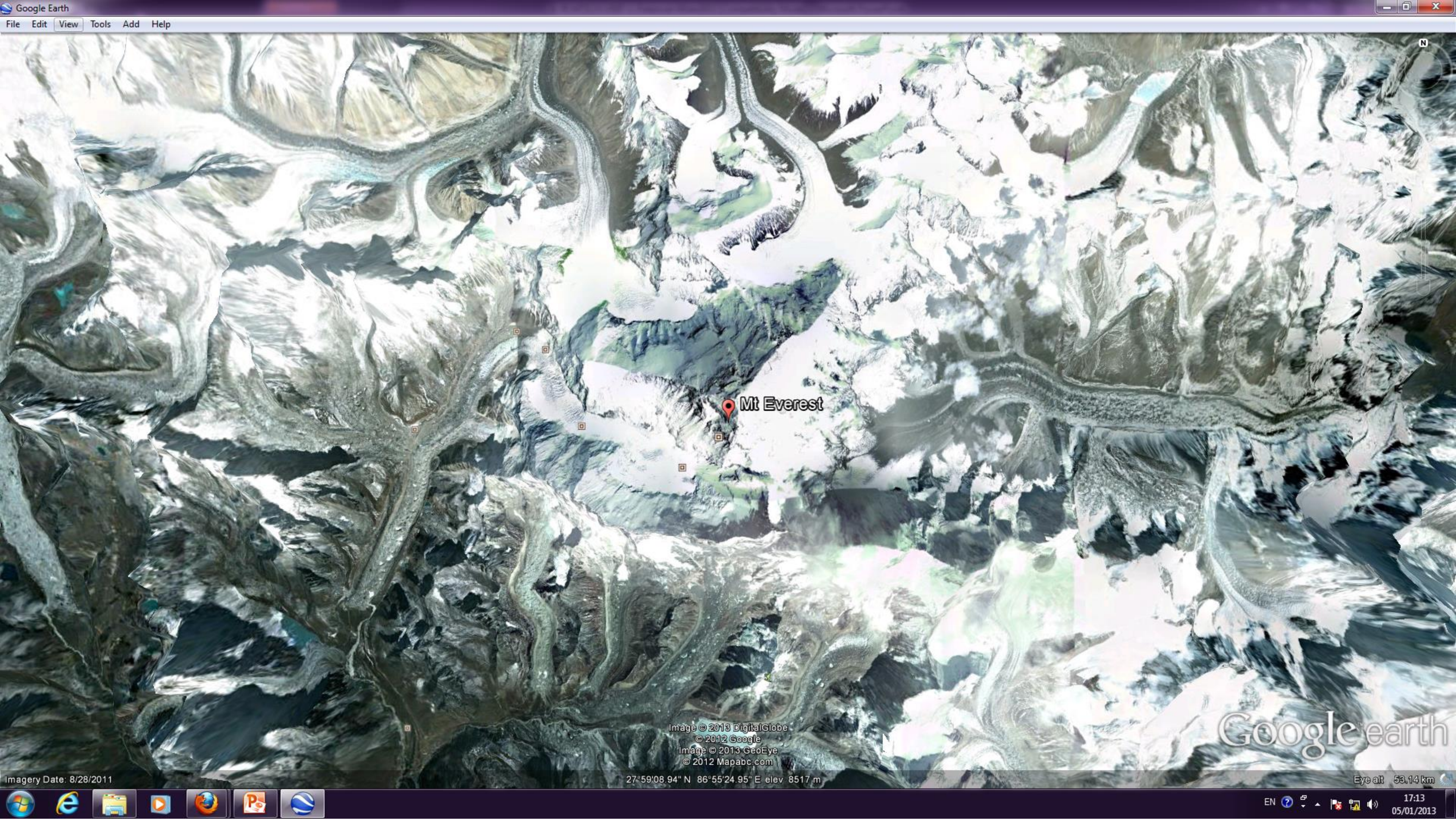
Sahara desert – Sand rivers – from Google earth

Wind action – Aeolian Geomorphological landforms - Sahara desert – Sand dunes – from Google earth





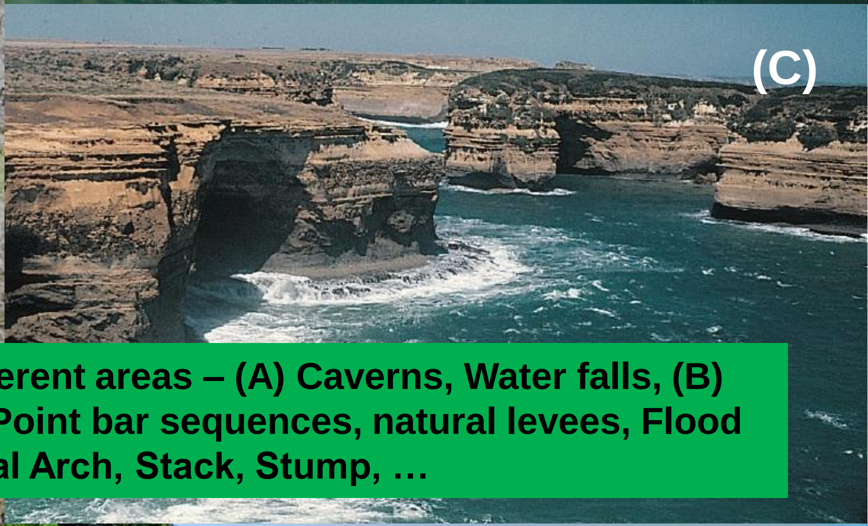
Parabolic Sand dune – sand hill – panoramic terrestrial photograph – To know the size of this hill (photo scale), see the three humans are walking along the farther limb of this dune – shown by an arrow



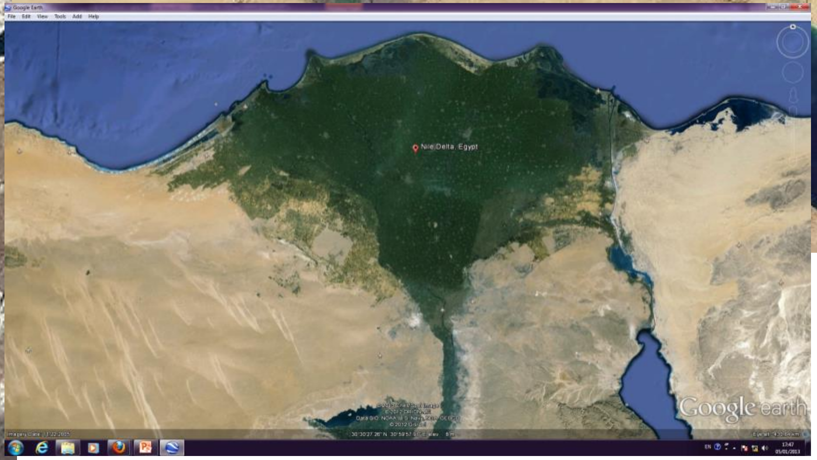
Permafrost – Glaciated areas - Ice desert – Ice rivers – Mt. Everest from Google earth showing U shaped valleys, Lateral, Mid & Terminal Morains …

Terrain 3D view - Ice desert – Ice rivers – Morains and ‘U’–shaped valleys are visible - Mt. Everest Glacier from Google earth

Water – Fluvial action possess a very strong force and energy – can cut across the very hard rocks



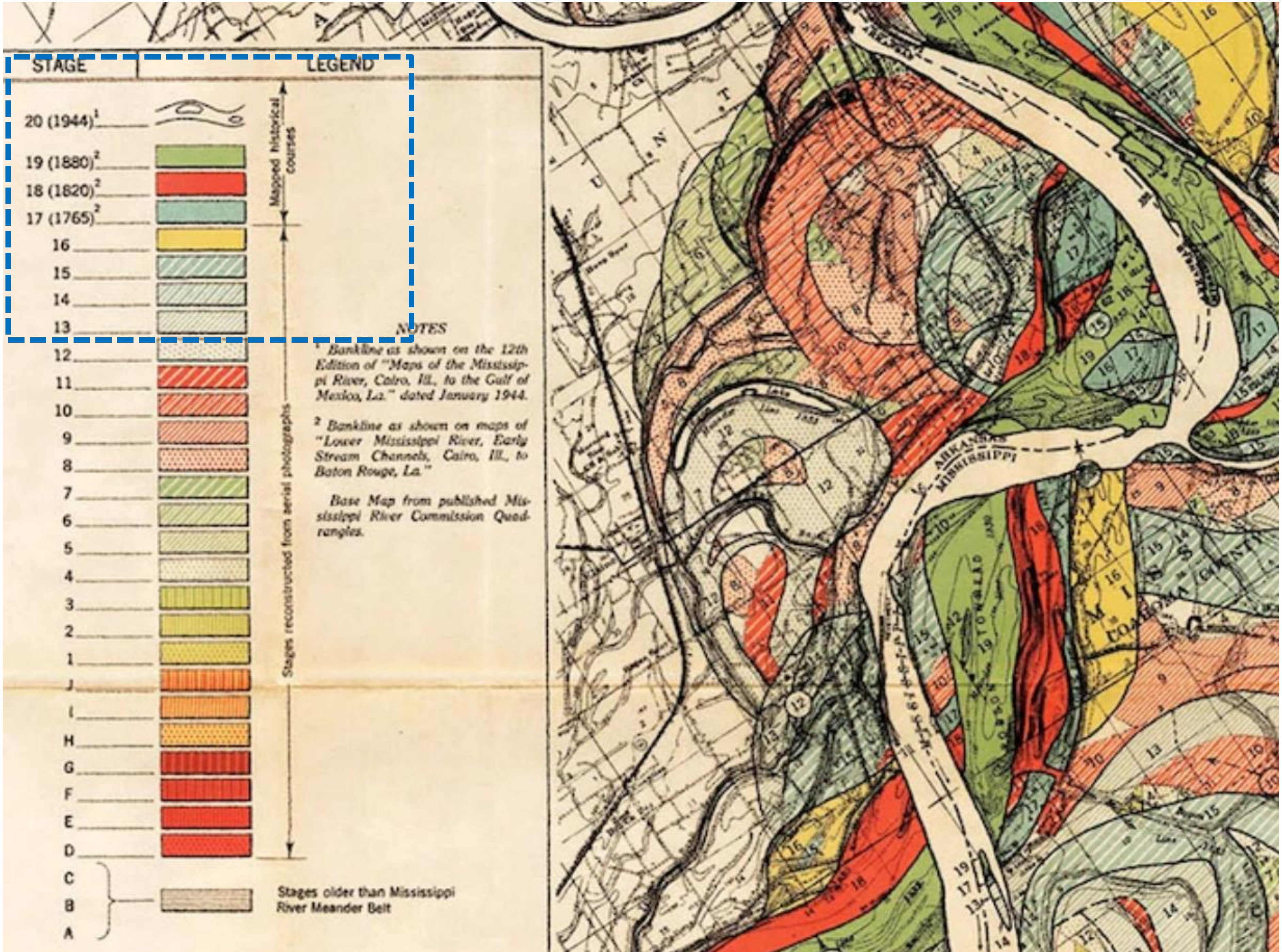
Water – develops different types of landforms in different areas – (A) Caverns, Water falls, (B) Meandering rivers, Cut-off meanders, Ox-bow lakes, Point bar sequences, natural levees, Flood plains, (C) Coastal Headland, Natural Arch, Stack, Stump, …



Satellite Images of Riverine / Fluvial Landforms

Above – Delta formed by the River Nile, Egypt

Left - Migrating Rivers – Related landforms – Oxbow lakes, Palaochannels, Meanders, etc.


STAGE
LEGEND
20 (1944)1
19 (1880)2
18 (1820)2
17 (1765)2
16
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Mapped historical courses
Stages reconstructed from aerial photographs
Stages older than Mississippi River Meander Belt
NOTES
1 Bankline as shown on the 12th Edition of "Maps of the Mississippi River, Cairo, Ill., to the Gulf of Mexico, La." dated January 1944.
2 Bankline as shown on maps of "Lower Mississippi River, Early Stream Channels, Cairo, Ill., to Baton Rouge, La."
Base Map from published Mississippi River Commission Quadrangles.
ARKANSAS
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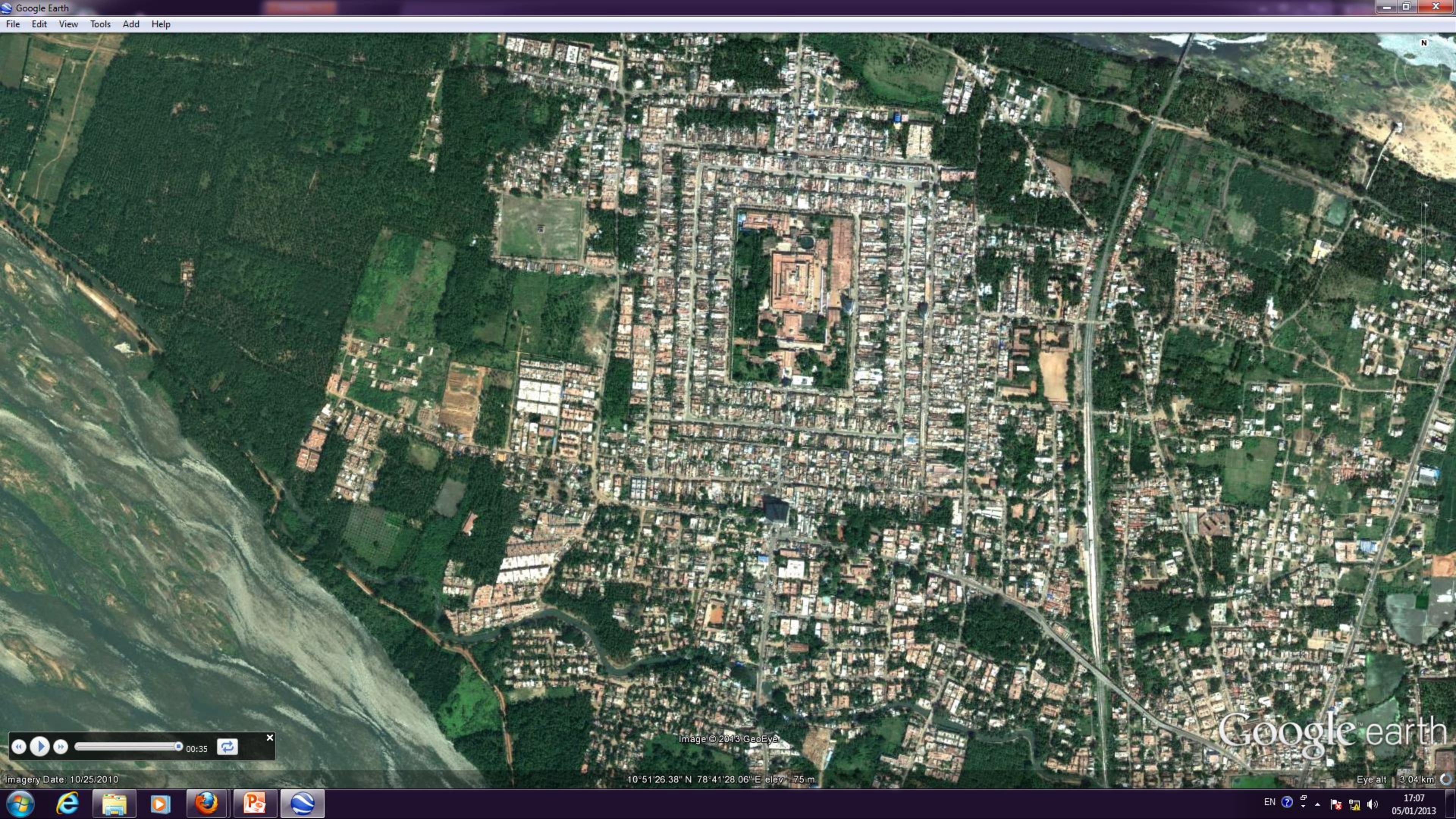
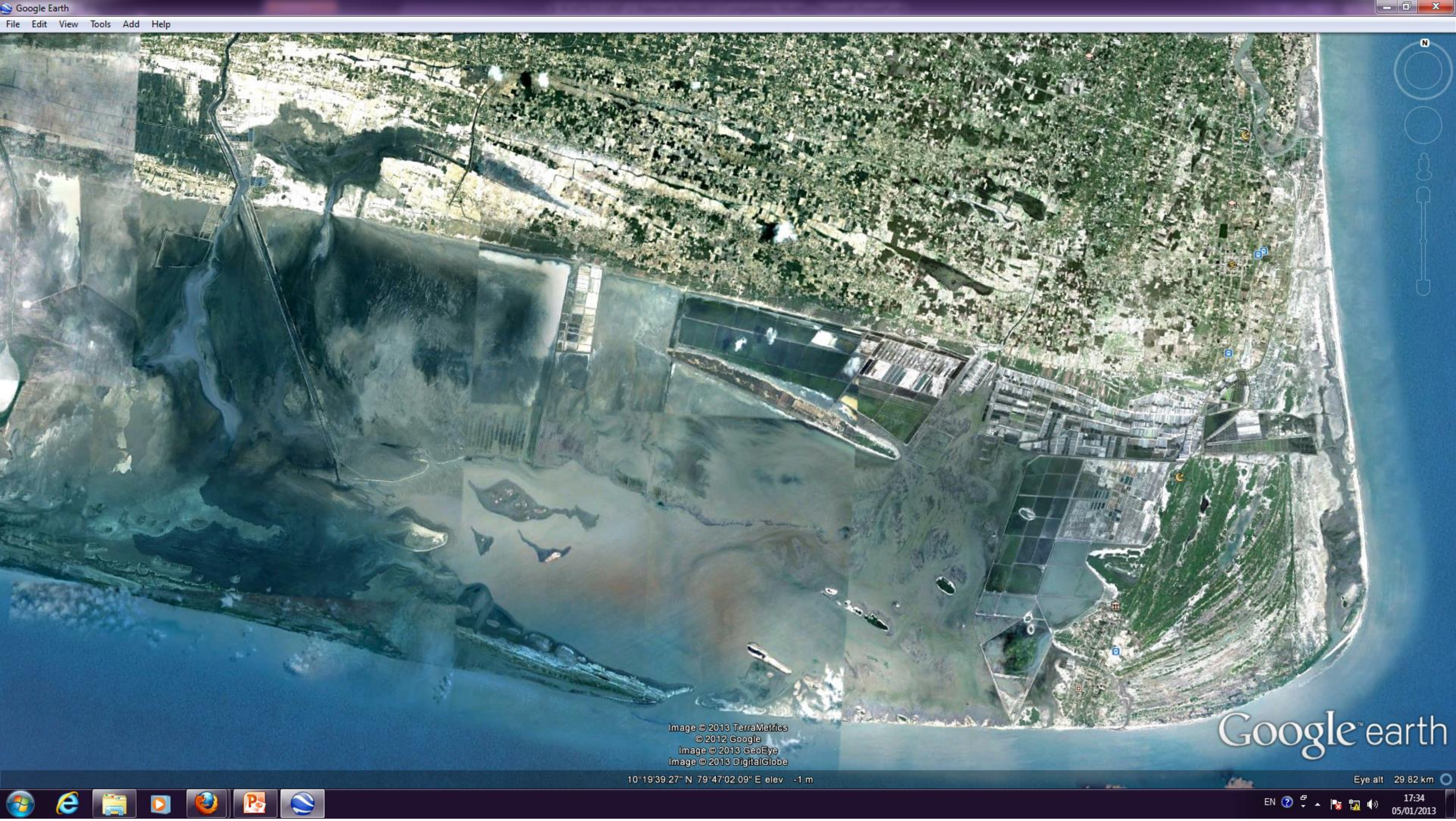


River Island - from Google earth – Can u guess, which area it is….

Satellite Image showing Structural, Tectonic, Denudational, Riverine and Coastal Geomorphological Landforms

Part of Middle Tamil Nadu covering Kolli-Pachchai hills (North), Cauvery Delta (East), parts of Kodaikkanal, Kadavur – Sirugudi (cut onion shaped) and Sirumalai hills (SE)

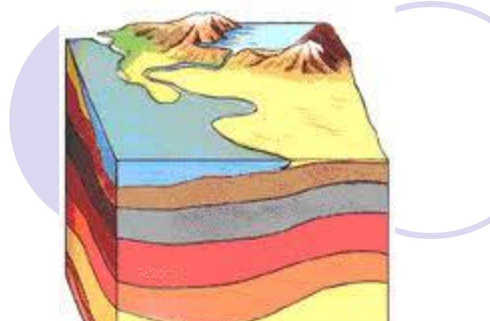


Satellite Image of Coastal Geomorphological Landforms

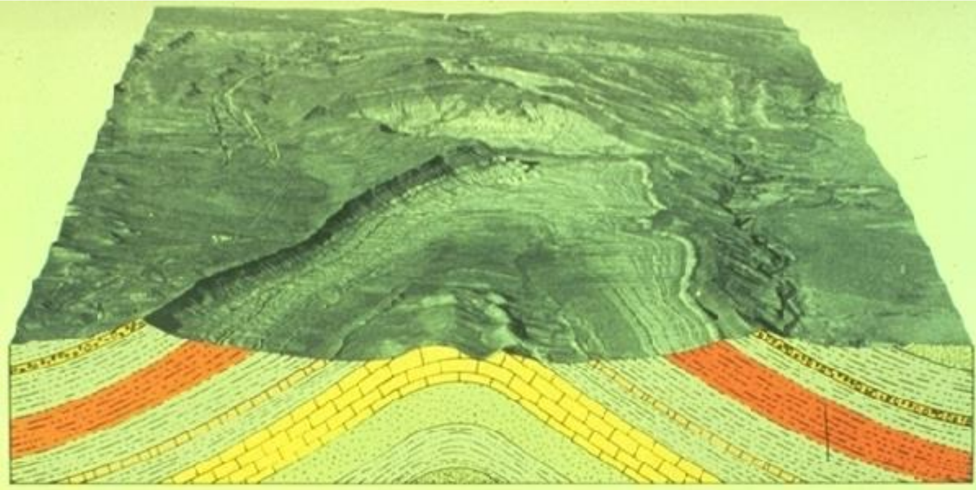
Part of Vedaranniyam area showing coastal landforms – Beach Ridges, Swales, Tidal and Mud flats, etc.

Satellite Image of Structural Features

Block diagram of various rock layers undergoing platetectonic disturbances



We will see a different view of the similar such structural hill area viewed by another satellite called GeoEye in the forth coming slides

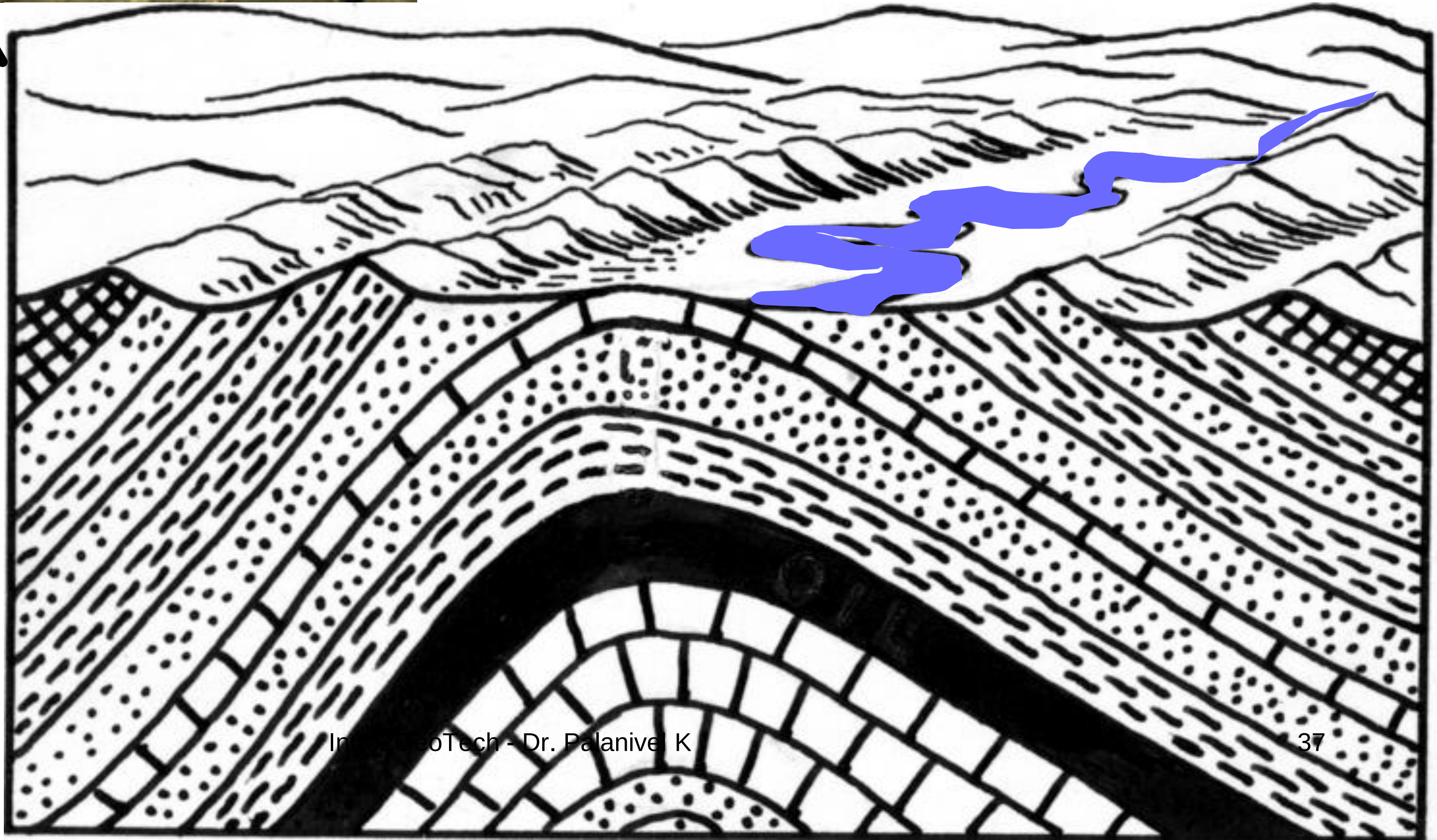


Plunging fold interpreted into the subsurface.

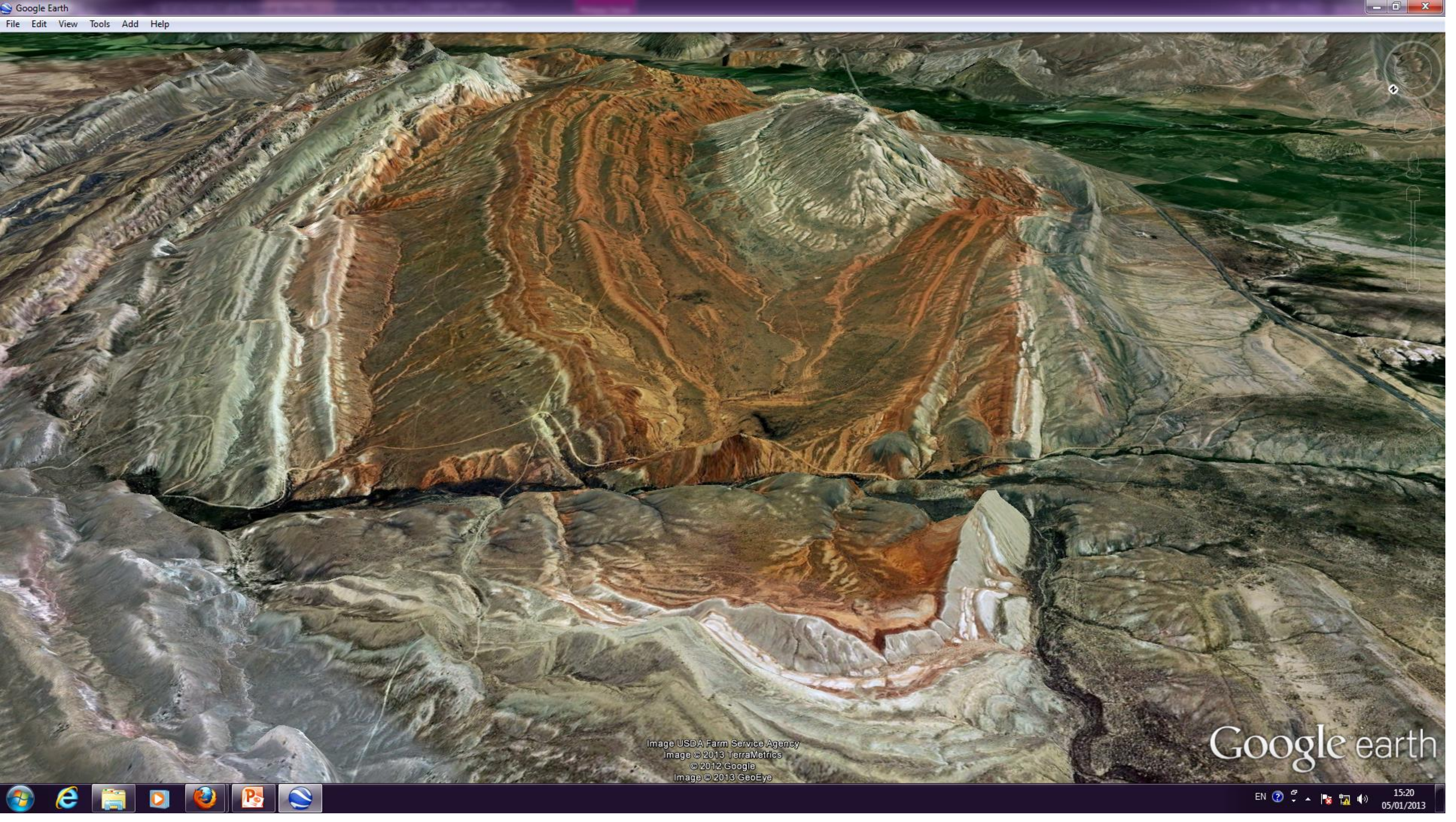
Above:Aerial photograph of Sheep Mountain - a **doubly plunging** anticline (NW WY). "V" s are pointing the direction of the plunges. Erosion due to the Gros Ventre River along the south flank resulted in a spectacular landslide in 1925.

Oblique Surface view showing landscapes above anticlinal structure

Vertical Cross Section of Block diagram showing the subsurface folded rock stratum

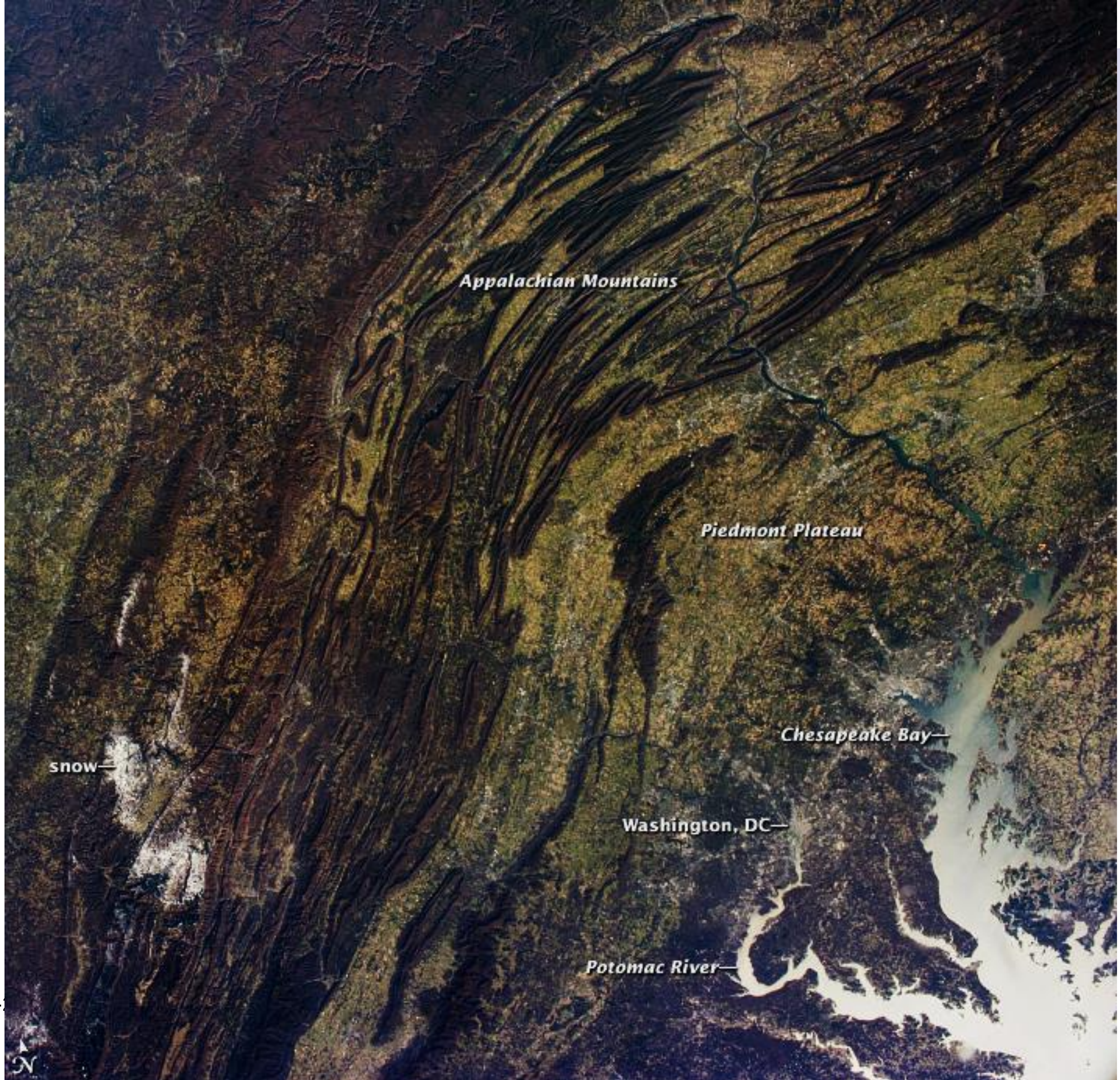


Sheep Mountain, Albany, Wyoming WY, United States – GeoEye satellite data viewed using Google earth



Sheep Mountain, Albany, Wyoming WY, United States – viewed using 3D terrain option of Google earth





Appalachian Mountains
Piedmont Plateau
Chesapeake Bay
snow
Washington, DC
Potomac River

This regional view shows the striking visual effect of the valley-and-ridge topography of the Appalachian Mountains as viewed from the International Space Station. The image shows more than 500 kilometers (300 miles) of this low mountain chain from northeast Pennsylvania (top right) to southern West Virginia, where a dusting of snow covers a patch of land (lower left).

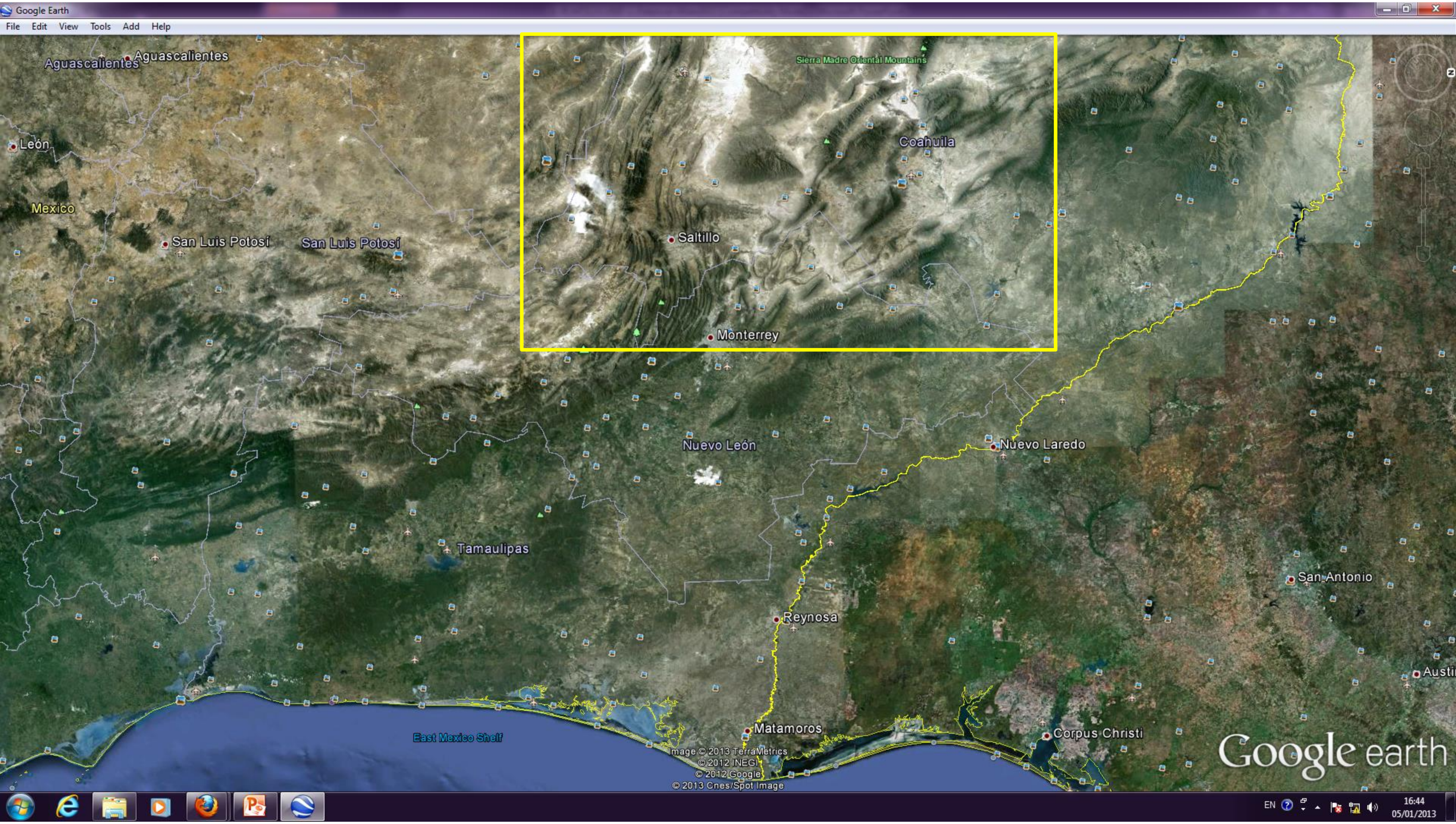
Sunglint reflections reveal details of Chesapeake Bay and the great bend of the Potomac River. Cities are difficult to detect from space during daylight hours, so the sickle-shaped bend of the river is a good visual guide for astronauts trying to photograph the nation's capital, Washington D.C. The farm-dominated Piedmont Plateau is the light-toned area between the mountains and the bay.

The Appalachian Mountains appear striped because the ridges are forested, providing a dense and dark canopy cover, while the valleys are farmed with crops that generally appear as lighter-toned areas. (Farmland is even lighter than usual in this image because the fields are fallow after the harvest.) Geologically, the valleys are the softer, more erodible rock layers, much the preferred places for human settlement. Not only do the larger rivers occupy the valley floors, but the soils are thicker, the slopes are gentler, and the valleys are better protected from winter winds.

The rocks that form this valley-and-ridge province, as it is known, are relatively old (540 to 300 million years old) and were laid down in horizontal layers when North America was attached to Europe in the ancient supercontinent of Laurasia. During this time Gondwanaland—an ancient supercontinent that included present-day Africa, India, South America, Australia, and Antarctica—was approaching Laurasia under the influence of plate tectonics. The northwest coastline of modern Africa was the section of Gondwanaland that "bumped up" against modern North America over a long period (320 to 260 million years ago).

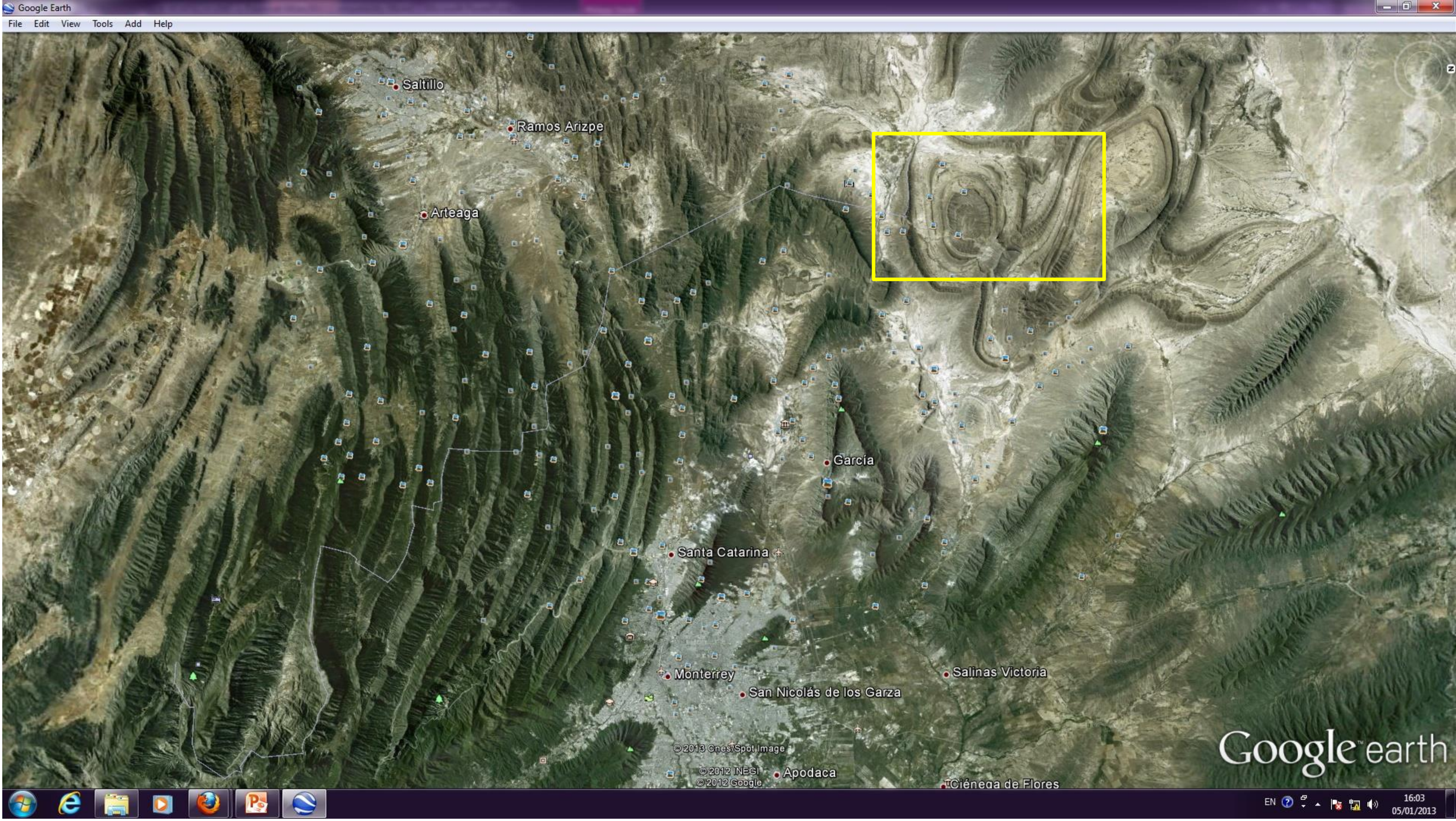
The net result of the tectonic collision was the building of a major mountain chain, much higher than the present Appalachian range. In the process, the flat-lying rock layers were crumpled up into a series of tight folds, at right angles to the advance of Gondwanaland. The collision also formed the singular supercontinent of Pangaea. Over the following 200 million years, Pangaea broke apart; the modern Atlantic Ocean formed; and erosion wore down the once-high mountains. What is left 200 million years later are the coastline of North America and the eroded stumps of the relatively low, but visually striking mountain chain.

Astronaut photograph ISS033-E-22378 was acquired on November 17, 2012, with a Nikon D3S digital camera using a 28 millimeter lens, and is provided by the ISS Crew Earth Observations experiment and Image Science & Analysis Laboratory, Johnson Space Center. The image was taken by the Expedition 33 crew. It has been cropped and enhanced to improve contrast, and lens artifacts have been removed. The International Space Station Program supports the laboratory as part of the ISS National Lab to help astronauts take pictures of Earth that will be of the greatest value to scientists and the public, and to make those images freely available on the Internet. Additional images taken by astronauts and cosmonauts can be viewed at the NASA/JSC Gateway to Astronaut Photography of Earth. Caption by M. Justin Wilkinson, Jacobs/ESCG at NASA-JSC.



Carricitos - Sierra Mountain, Monterry, United States – viewed using Google earth – Let us zoom a small portion (yellow rectangled) of this image

Carricitos - Sierra Mountain, Monterry, United States – viewed using Google earth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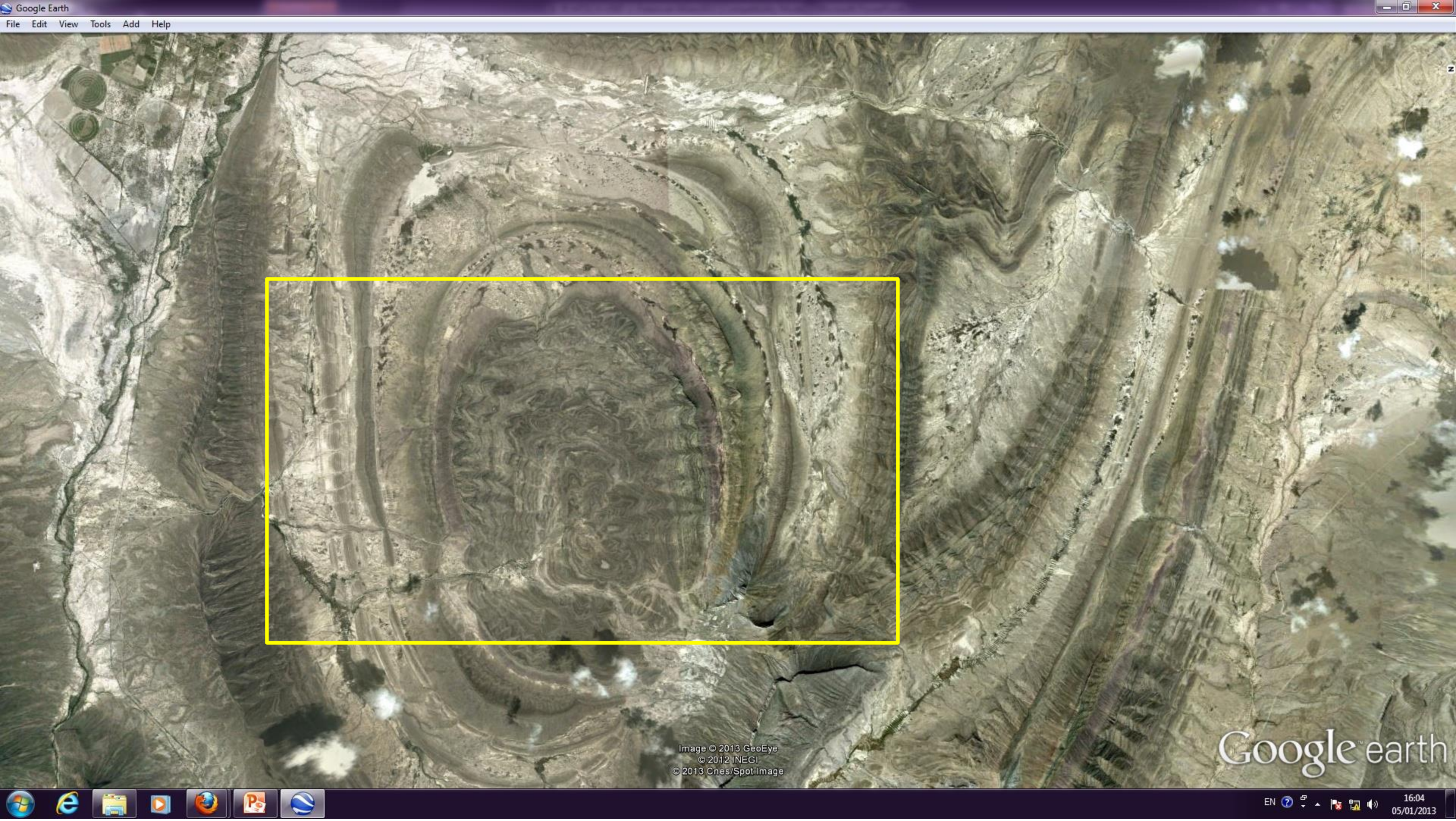
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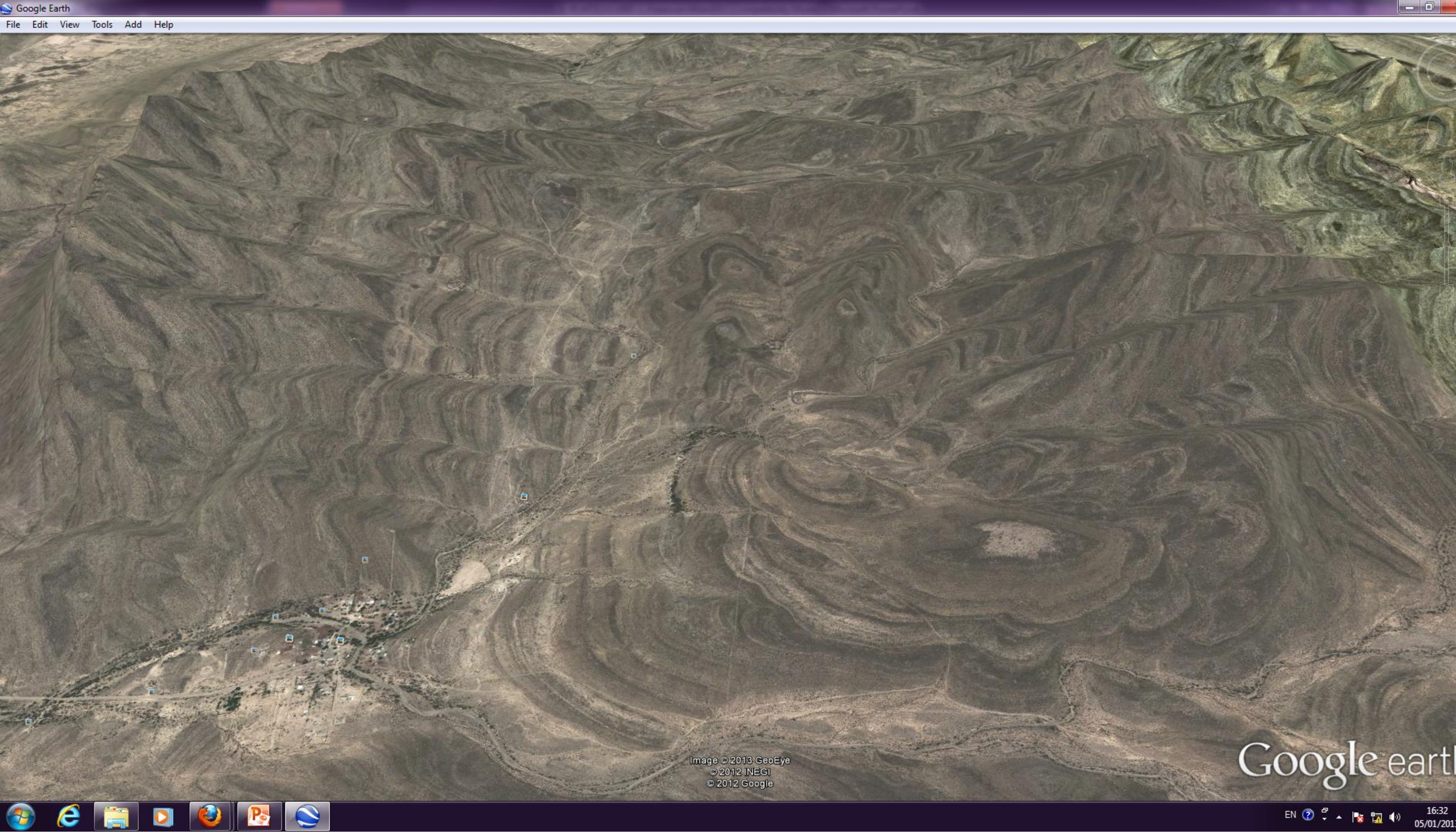
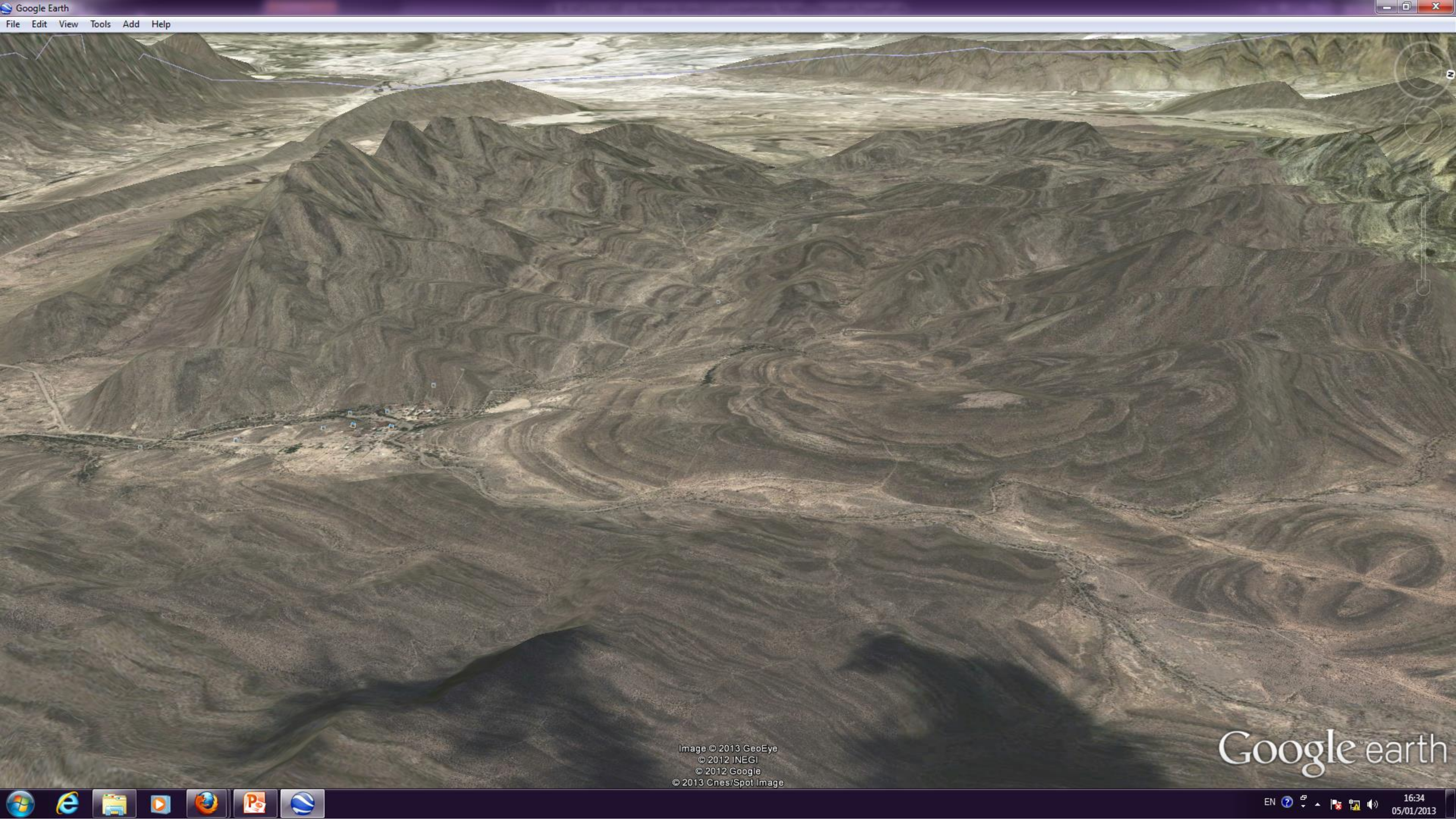
Escarpments, i.e., Steep sided portion of hills Structural Features shown both in satellite image, high oblique aerial photograph and terrestrial photograph

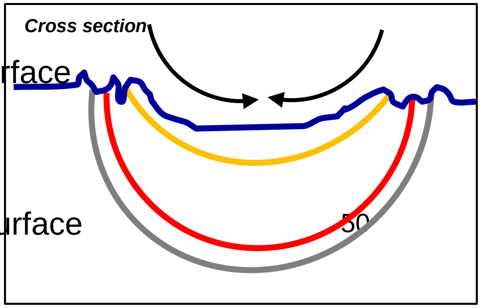
3D view of Escarpments - Satellite Image and field photograph



Note, there are multiple rock layers visible having alternating light and dark colours – each rock layer can be traced very well – Have a look on Western and Eastern side rock layers of this 3D image – Note the direction of ‘V’ point seen along either sides of drainages. If you are not clear, see the next slide showing a 3D image from lower elevation and high oblique angle (in which the distant hills are also appearing….)



Doubly Plunging Synclinal structure (i.e. inclined towards the center) of Carricitos - Sierra Mountain, Monterry, United States – viewed using Google earth



Other Branches of Earth Sciences and Definitions:

Agro geology - Study of minerals of importance for farming , agriculture, horticulture, etc.

Physical Geology / Dynamic Geology - Concerned with the process and products of forces for evolution of Earth and its morphology

Physiography and Geomorphology – Study deals with general configuration of the earth's Surface – Landforms

Physiography – is the descriptive part of the landforms

Geomorphology – interpretation on the basis of landforms

Petrology- **Study of physical and chemical properties and constitution of rocks**

Petrography – study of mineralogical textural relationship

Lithology – Physical characters and feature of rocks

Petrogenesis – Origin and formation of rocks

Sedimentology - Overall study of sedimentary rocks – its origin, processes of sedimentary deposition and classification.

Palaeontology - It deals with study of past life in the form of animal and plant fossils preserved in the rocks

Palaeobotony, palynology, micro palaeontology – study of fossils classification and nomenclature, morphology, relation with other organism, phylogeny (line of direct descent)

Mineralogy - Study of minerals – its composition, physical properties, crystal structure, formation, occurrence and classification

Crystallography – Branch of science concerned with the physical properties of crystals and their aspects

Palaeoecology – Palaeo environment and palaeo climate information through the fossils and the associated rocks.

Structural Geology – deals with forms, arrangements and internal structure of rocks developed during rocks formation and subsequently by deformation – Tectonics and global tectonics are related terms

Stratigraphy - Study of various rocks Chronological succession, relative ages, correlation with each other in space and time (Palaeontology play vital role)

HISTORICAL GEOLOGY: Entire history of the Earth from its origin to present day

ECONOMIC GEOLOGY: It is the study of analysis of geologic bodies and materials that can be utilized profitably by man–Mineralization, Metallogeny

GEOCHEMISTRY: It is the Science of the distribution of chemical elements in minerals, ores, rocks, soils, water and their ions and isotopes

ISOTOPE GEOLOGY: Determination of ages of minerals and rocks using some radio active and stable isotopes of certain elements – establishing reliable chronology.

V-pb; K-ar; Rb-Sr; sm-We, Radio carbon and fission track

ENGINEERING GEOLOGY: Geology as applied to engineering practices –Planning, designing, operation and maintenance of civil engineering works.

HYDROGEOLOGY: Study relate to occurrence and movements of subsurface water and related geological aspects of surface waters.

ASSOCIATED DISCIPLINE:

ENVIRONMENTAL GEOLOGY: **Study of geological impact on environment (eg. Mining Project, Solid and Liquid waste disposal etc)**

MINING GEOLOGY: **Study of geological aspects of mineral deposits with particular to problems related to its mining Prospecting, Exploration, Geological, Geochemical and Geobotanical survey etc)**

MEDICAL GEOLOGY: **Study of rocks and minerals with respect to health of living things, mainly humans (Toxicity of elements)**

EXPERIMENTAL GEOLOGY: Lab based studies of rock formation.

PEDOLOGY: Study of soils which are the products (weathered rock) of rock decay.

LIMNOLOGY: Study of lakes, Ponds, Water bodies their physical, biological and ecological attributes evaluation.

GEOGRAPHY: Science of earth surface physical features, climates vegetation, soils and their distributions.

METALLURGY : Science and Technology of extracting and purifying metals.

ORE DRESSING: Methodology of Mechanical and other processes of concentration of Metals and Minerals from ore.

GEOPHYSICS: Science of physical processes applied for studying the various aspects of earth sciences encompassing lithosphere, hydrosphere and atmosphere.

GEODESY: Science dealing with determining and measuring precise shape of our Earth, its orientation in space and its gravity.

PALAEOMAGNETISM: Study of magnetic fields recorded in rock – the remnant magnetism records during the formation of rock.

OCEANOGRAPHY AND MARINE GEOLOGY:

Scientific study of the ocean in all aspects – its relief, petrology, geochemistry, currents, waves, sea bottom, coastal structure and land form (coastal geomorphology)

METEOROLOGY:

Science of Atmosphere – it's a branch of Earth Science deals about rain and temperature and its impact on distraction of rocks .

Why GEOTECHNOLOGY is important?

- **The GEOTECHNOLOGY which includes the science of geology, is significant in**
  - **Locating water supplies, mineral resources,**
  - **Understanding the development of life on Earth,**
  - **Developing predictive models for earthquake, volcano, and tsunami activity, and**
  - **Adding fundamental knowledge to the field of Earth and planetary sciences.**

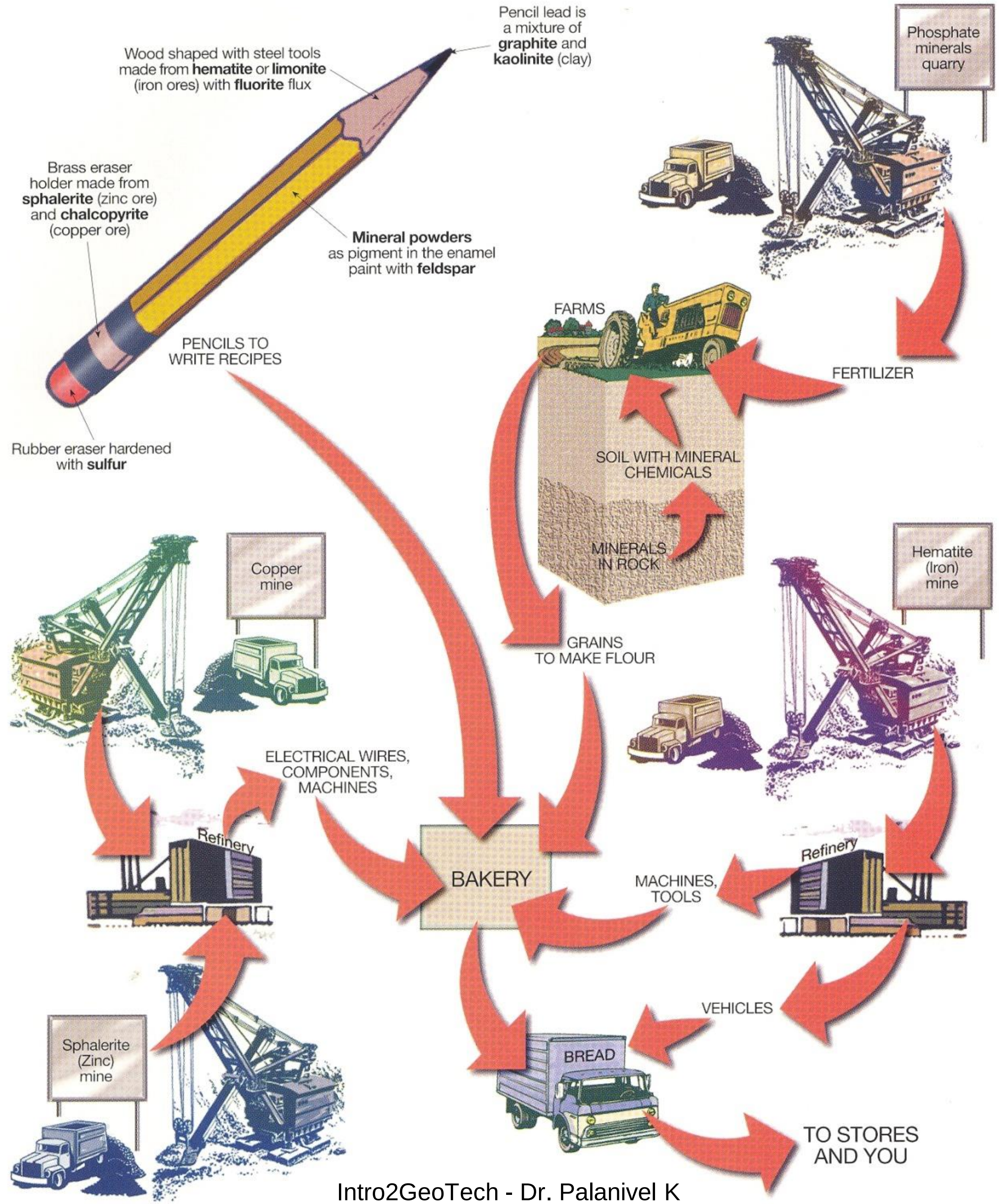


FIGURE 2.2 Flow diagram illustrating how minerals have been used to manufacture some common items that you probably use or eat everyday.

Geotechnology is important in

- Determining building placement / proper basement,
- Discovering resources such as gravel, building stone, oil, coal, water, gem stones and mineral deposits,
- Gaining knowledge of rock and mineral properties, landslide avoidance, erosion control,
- Determining planetary histories, and earthquake and volcano eruption prediction.

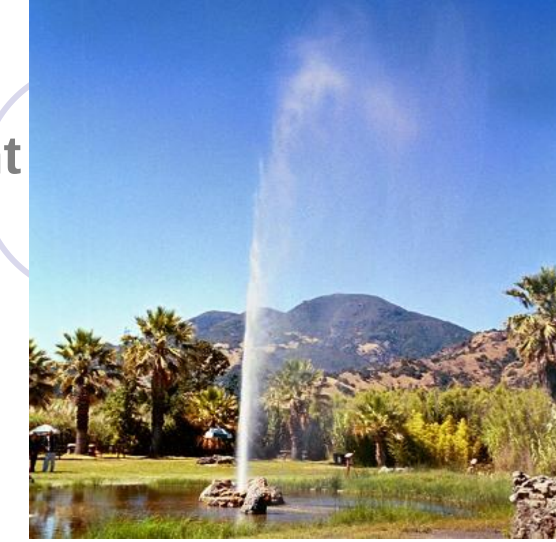
IMPORTANCE OF GEOTECHNOLOGY

- Nearly everything we use in our daily life, from sidewalks to computers to homes, are constructed of components of rocks, or of plant material relying on the minerals in rock for growth.
- Earth Science plays a unique and essential role in today's rapidly changing world.
- It is an integrated study of the Earth's history, composition and structure, its atmosphere and oceans, and its environment in space.
- Knowledge of Earth Science is important because most human activities are related to interaction with the planet Earth.

Natural Resources – **Exploration, Exploitation, Conservation, Management**

Natural Disasters - **Mitigation, Forewarning, Management, Damage Assessment**

All these are possible. How?



Geyser@Calistoga, California

- By understanding the Formation / Origin & conditions of Occurrence about the Natural Resources
- By understanding the causative / inducing parameters of Natural Disasters
- By understanding the Earth system processes

EARTH SYSTEM PROCESSES

Earth Sciences: As discussed,

It is the science of understanding of our planet Earth:

- **its land, ocean, atmosphere, planets and life forms**
- **its processes, its resources and its environment.**

⇨ **Our lives and civilization depends upon how do we understand, interact, behave & manage with our mother planet Earth - ESPs.**

Earth System Processes affect us all

- Weather pattern influence the availability of water resources
- Natural Hazards can kill large number of people and cause damage to his properties.

We in turn affect our planet

- ⇨Growing population and related increasing demand for various natural resources
- ⇨Improper development cause or trigger disasters.

So, in order to enhance our stewardship of our environment

- ⇨We must proceed into the future with sound understanding of Earth Systems.

Earth Science Learning:

Exposures to think globally and act locally,

⇨ **To make sound decisions about issues important to our lives**

⇨ **If we understand how the earth systems works, then we**

- **Can make informed decisions**
- **Can resolve issues related to Natural resources, Ecosystems and Natural disasters**

So,

The future lies in the hands of Geoscientists / Geotechnologists / Geotechnocrats.

Earth Sciences Provides

- ⇨An integrated and interdisciplinary approach
- ⇨It includes and applies knowledge from biology, chemistry, physics, ecology and mathematics to tackle interdisciplinary issues.
- ⇨So, the Earth Sciences is considered as

"Mother of all Sciences"

- ⇨Earth science education improves critical thinking skills
- ⇨It offers a historical perspective and
- ⇨Improves our ability to predict future events.

Past – Present – Future

Earth Science Education is an inquiry based approach.

Unlike the other experimental science (Physics, Chemistry) the Geology depends on observing and studying features on the earth.

➔So it largely depends on theory and hypothesis mostly based on logical thinking on facts and features observable today.

Earth System Processes

"PRESENT IS THE KEY TO THE PAST"

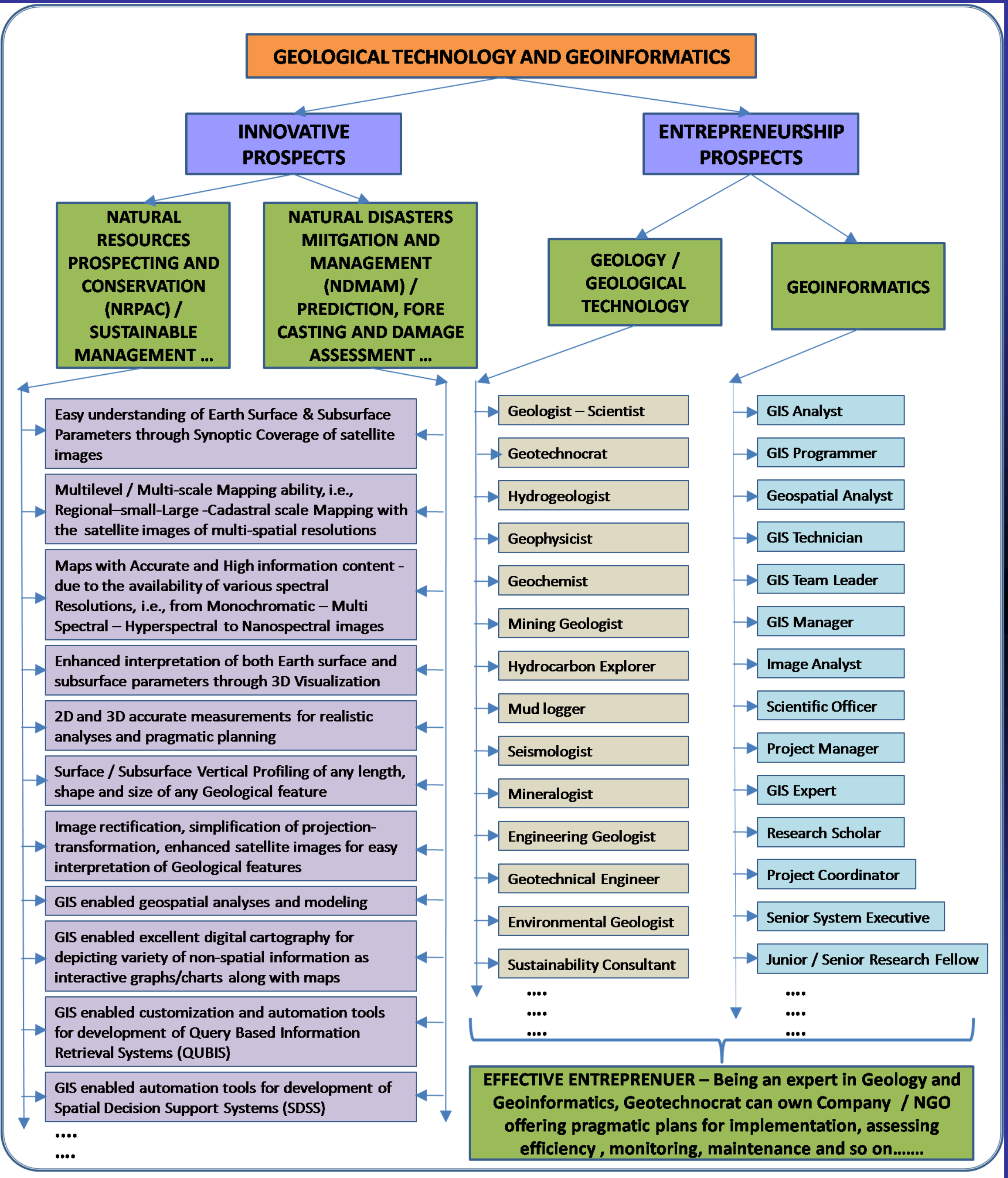
The processes that operate at present also operated in the past, but their intensity and rate vary – produce the same result.

SCOPE OF EARTH SCIENCES

The sub-disciplines of Earth Sciences are posing very high and direct relevance to the society and its sustainable economic and other developments and management or geohazard mitigation activities.

Hence, there are excellent and infinitive scopes to the core Geologists and it's experts in the advanced application fields (geosciences-geoengineeing-geolgical technology), i.e., Geotechnocrats.

The scopes of geotechnocrats are ranging from the basic data entry operators - geodatabase managers to geotech entrepreneurs.



A chapter on

"INNOVATIVE AND ENTREPRENEURIAL VISTAS IN GEOINFORMATICS ENABLED GEOLOGICAL TECHNOLOGY"

published in an Edited Volume entitled ***"Innovative Entreprenurship"*** under the RUSA of Bharathidasan University, Tiruchirappalli is available from the weblink:

https://www.researchgate.net/publication/359143557_INNOVATIVE_ENTREPRENEURIAL_VISTAS_IN_GEOINFORMATICS_ENABLED_GEOLOGICAL_TECHNOLOGY

UNIT-1B

EARTH SYSTEM PROCESSES

<u>Earth System Processes</u>: Origin, interior & age of the Earth – Plate tectonics – Formation of Continents & Oceans – Mountain building activities – origin of rivers – Physiography of the Earth.

.

ORIGIN OF EARTH

➔A lot number of theories have been proposed by various scientists. But no single theory fully explained the origin of solar system with valid reasons for physical and chemical features exhibited by system

➔All the theories can be grouped under three heads:

1. Evolutionary Theories: These are based on later modification of pre-existing gas clouds. Forces responsible for it are all internal.

2. Multistar Theories: Based on the collision or close by crossing of two or more stars. External force.

3. Protosun Theories: Sun is supposed to form earlier and latter gathered the interstellar materials to form the disc.

NEBULAR Hypothesis

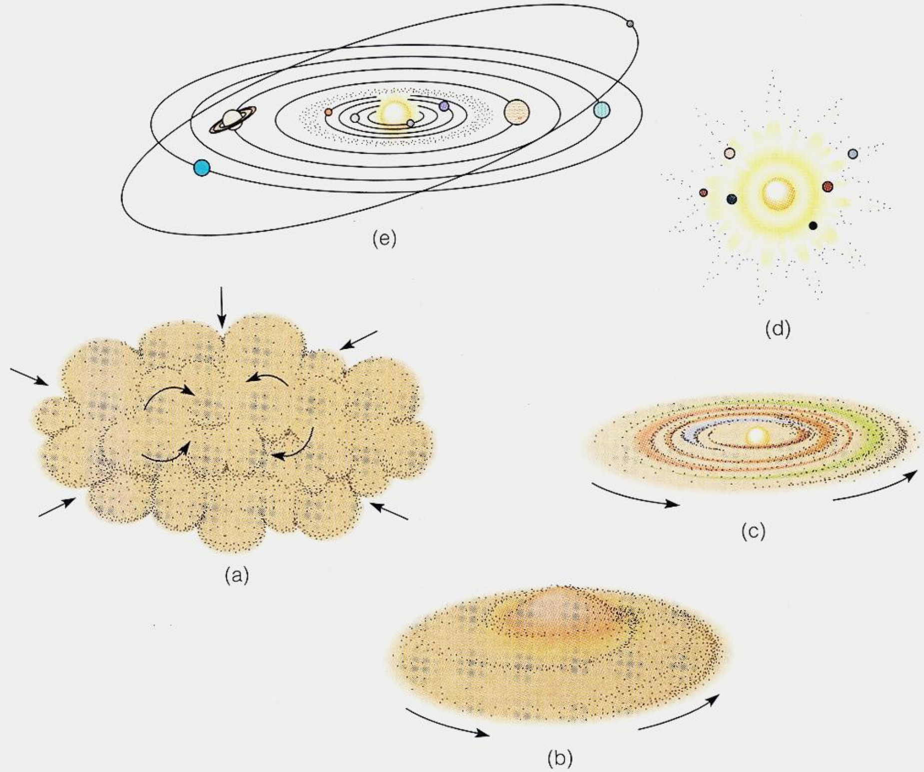
In 1755, **Immanuel Kant** (German Philosopher) proposed a hypothesis for the origin of Earth. 40 years later it was modified to suit the other requirements of the solar system by **Pierre-Simon Laplace** (Mathematician expertised in Celestial mechanics) of France.

This theory has been called as **Kant-Laplace's Nebular hypothesis**

According to the Kant-Laplace's Nebular hypothesis

- A rotating disc of hot gaseous nebula had been the parent body of the solar system
- This nebula got cooled because of energy lost by radiation
- The cooling of nebula lead to contraction and gravity
- This shrinking nebula started to rotate faster and faster in order to conserve angular momentum
- But at the boundary region of the nebula, because of rapid rotation, the centrifugal force became equal to gravitational force
- So, at this stage, materials of this region would maintain their orbital positions
- But continued contraction of inner portion had separated from the outer stable region
- The outer rings, in due course condensed into a planet
- In this way all the planets were formed
- The innermost materials become the Sun.

FIGURE 1.11 The currently accepted theory for the origin of our solar system involves (a) a huge nebula condensing under its own gravitational attraction, then (b) contracting, rotating, and (c) flattening into a disk, with the Sun forming in the center and eddies gathering up material to form planets. As the Sun contracted and began to visibly shine, (d) intense solar radiation blew away unaccreted gas and dust until finally, (e) the Sun began burning hydrogen and the planets completed their formation.



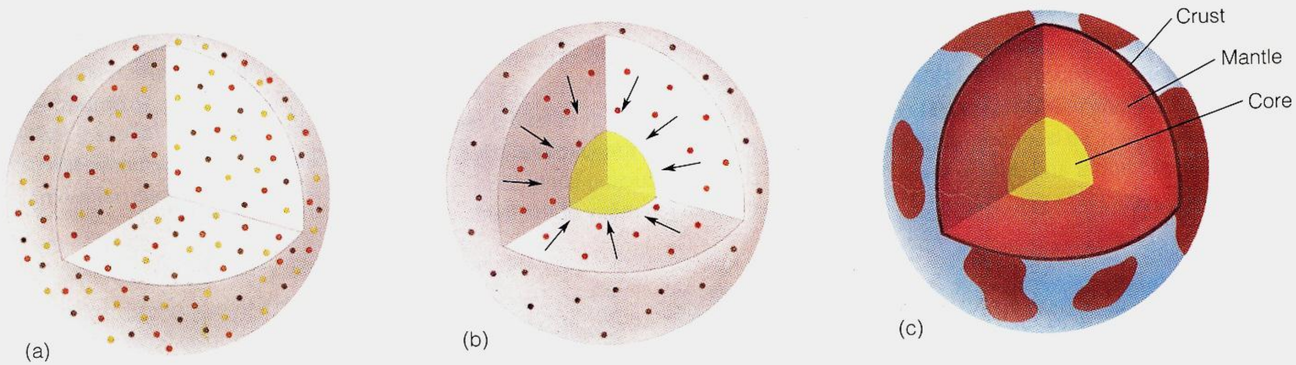


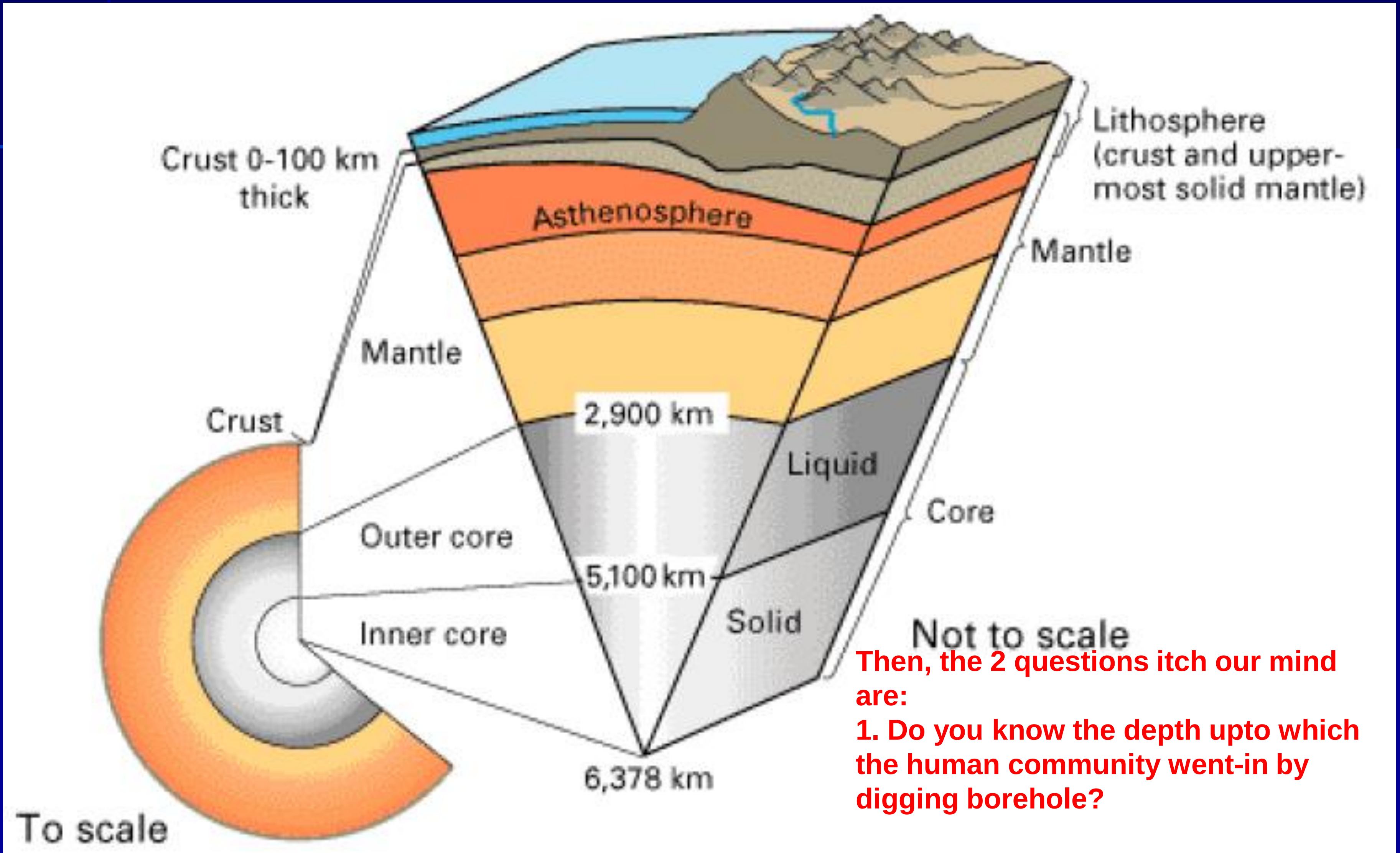
FIGURE 1.12 (a) Early Earth was probably of uniform composition and density throughout. (b) Heating of the early Earth reached the melting point of iron and nickel, which, being denser than silicate minerals, settled to Earth's center. At the same time, the lighter silicates flowed upward to form the mantle and the crust. (c) In this way, a differentiated Earth formed, consisting of a dense iron–nickel core, an iron-rich silicate mantle, and a silicate crust with continents and ocean basins.

(Figure 1.12c). This differentiation into a layered planet is probably the most significant event in Earth history. Not only did it lead to the formation of a crust and eventually to continents, but it was also probably responsible for the

AGE OF THE EARTH

- The oldest intact rocks found on Earth date back to about 3-4.0 billion years ago.
- Tiny grains of zirconium silicate (zircons) found embedded in sedimentary rocks have been radiometrically dated to 4.4 billion years ago.
- Moon rocks brought by Apollo astronauts are older than any Earth rocks – volcanism and other geological processes4.4 billion years ago.
- The Earth's crust appears to have already differentiated from the interior approximately 4.5 billion years ago
- Isotopic analysis of meteorites suggests the Earth and the rest of the solar system formed 4.57 billion years ago.
- From all the above, a safe figure for the maximum age of the earth is 4.6 billion years

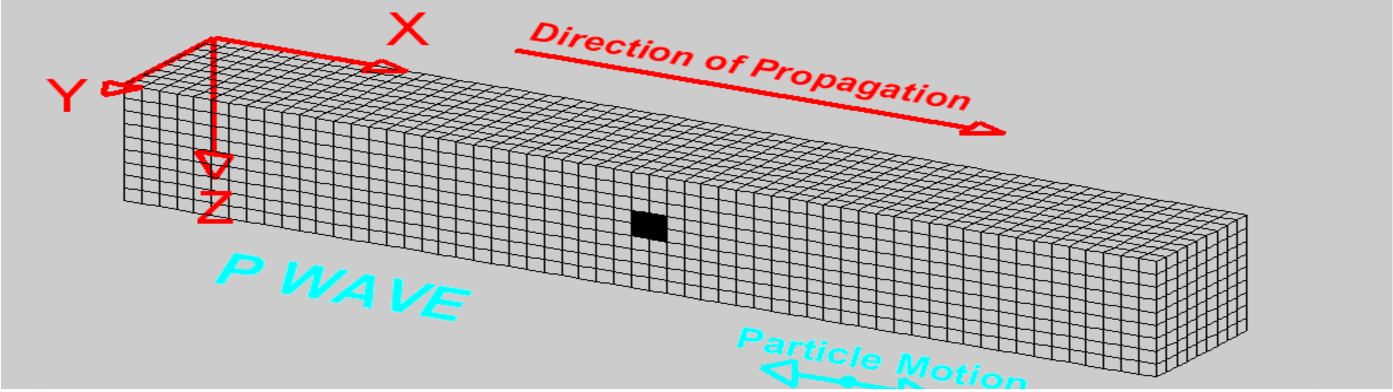
INTERIOR OF THE EARTH



Then, the 2 questions itch our mind are:

1. Do you know the depth upto which the human community went-in by digging borehole?

2. How do we know these facts about the inner Earth?



P-wave

Travels at an average Speed of 8.1 km/s

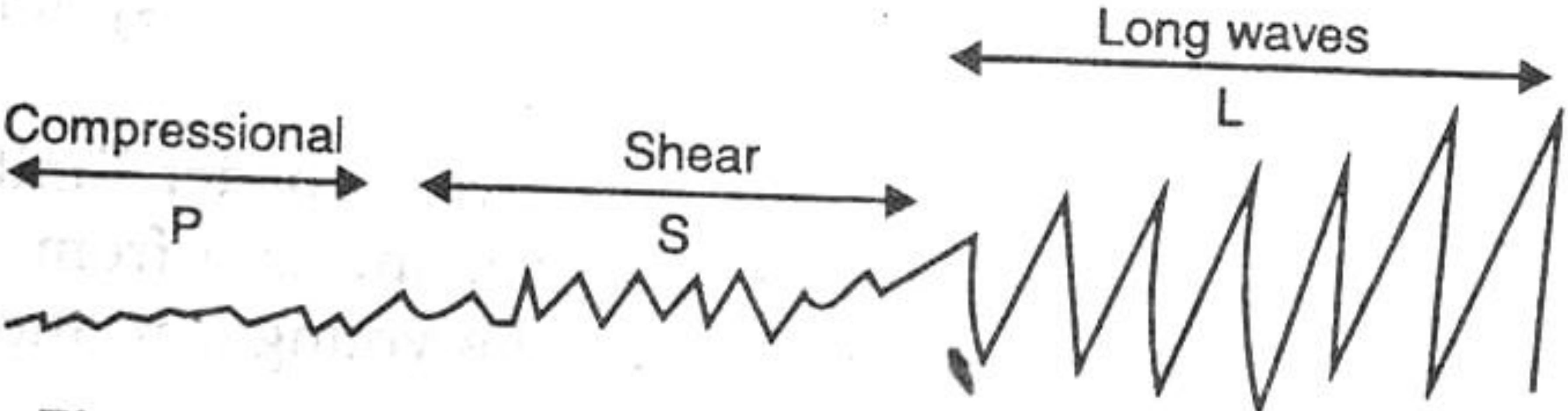
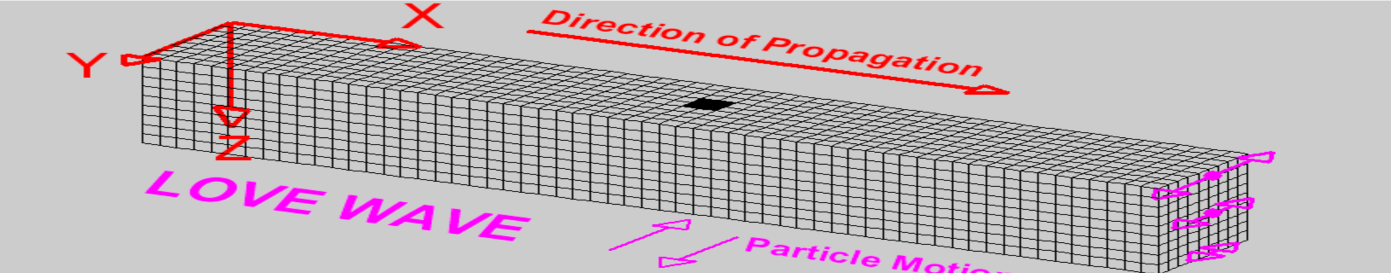
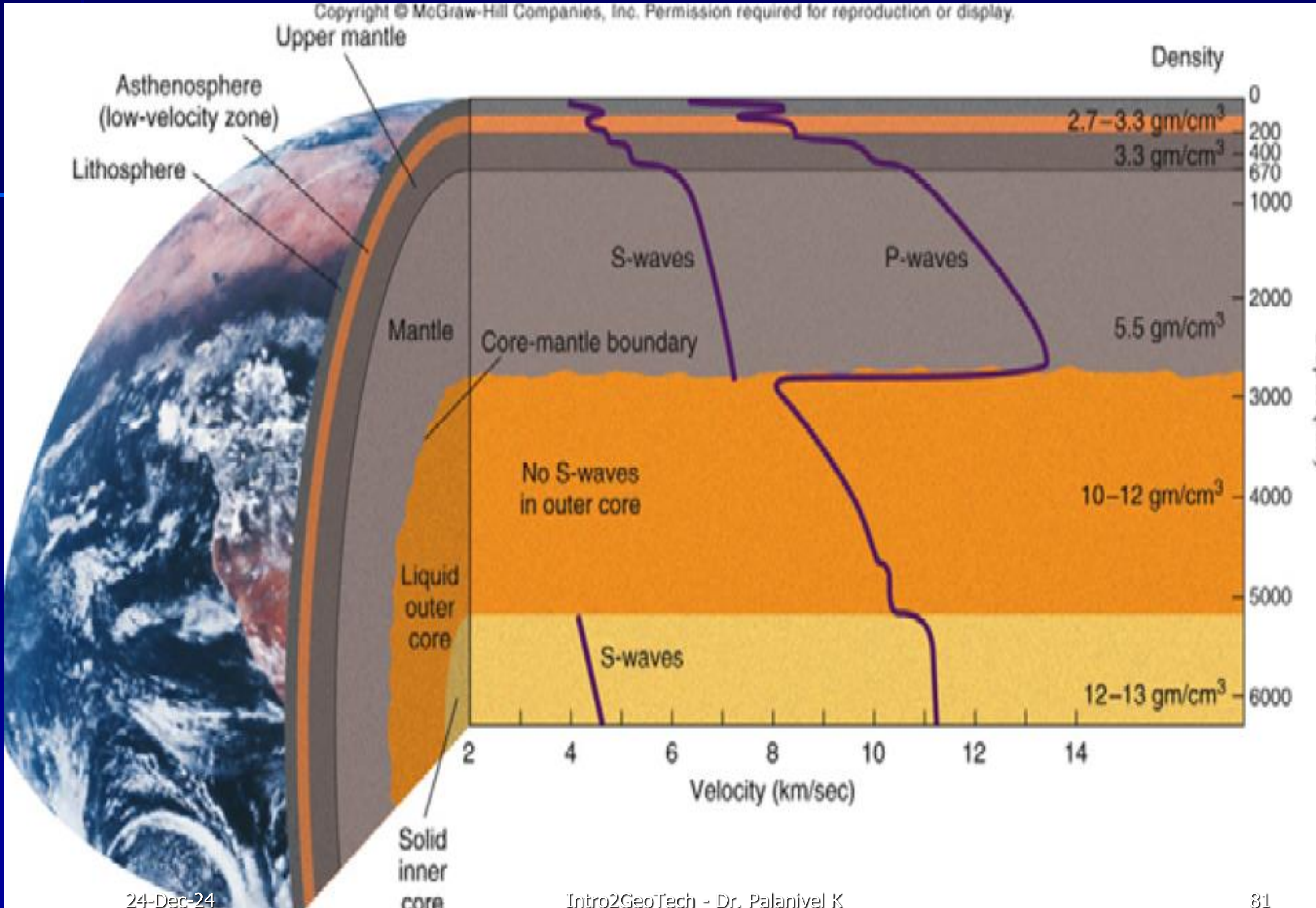


Fig. 2.3. A Typical Seismogram (Highly simplified).



amplitude, less velocity than ‘S’ wave - much stronger displacements



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Upper mantle
Asthenosphere (low-velocity zone)
Lithosphere
Mantle
Core-mantle boundary
Liquid outer core
Solid inner core
S-waves
P-waves
No S-waves in outer core
S-waves
Density
2.7–3.3 gm/cm³
3.3 gm/cm³
5.5 gm/cm³
10–12 gm/cm³
12–13 gm/cm³
0
200
400
670
1000
2000
3000
4000
5000
6000
Depth (km)
2
4
6
8
10
12
14
Velocity (km/sec)

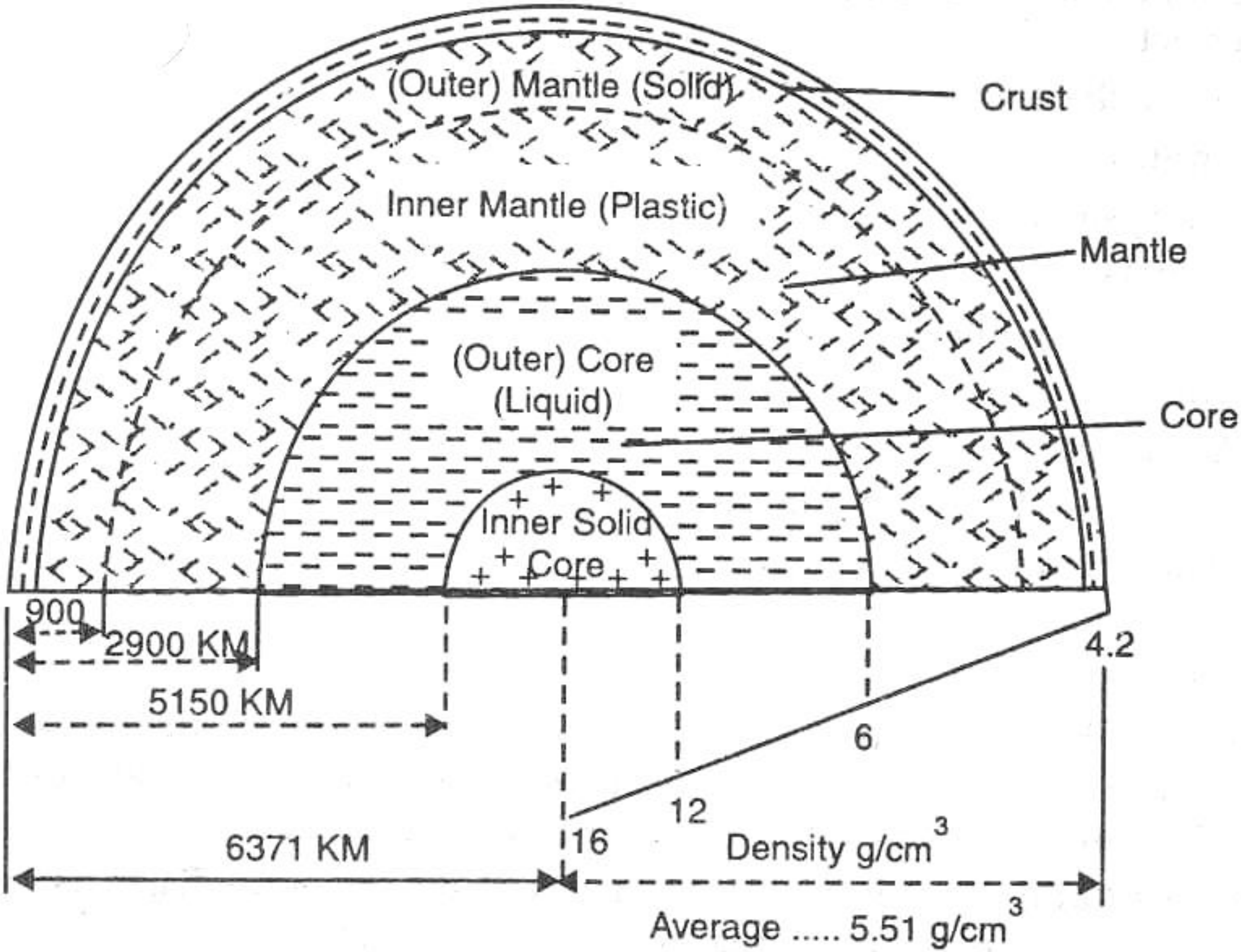
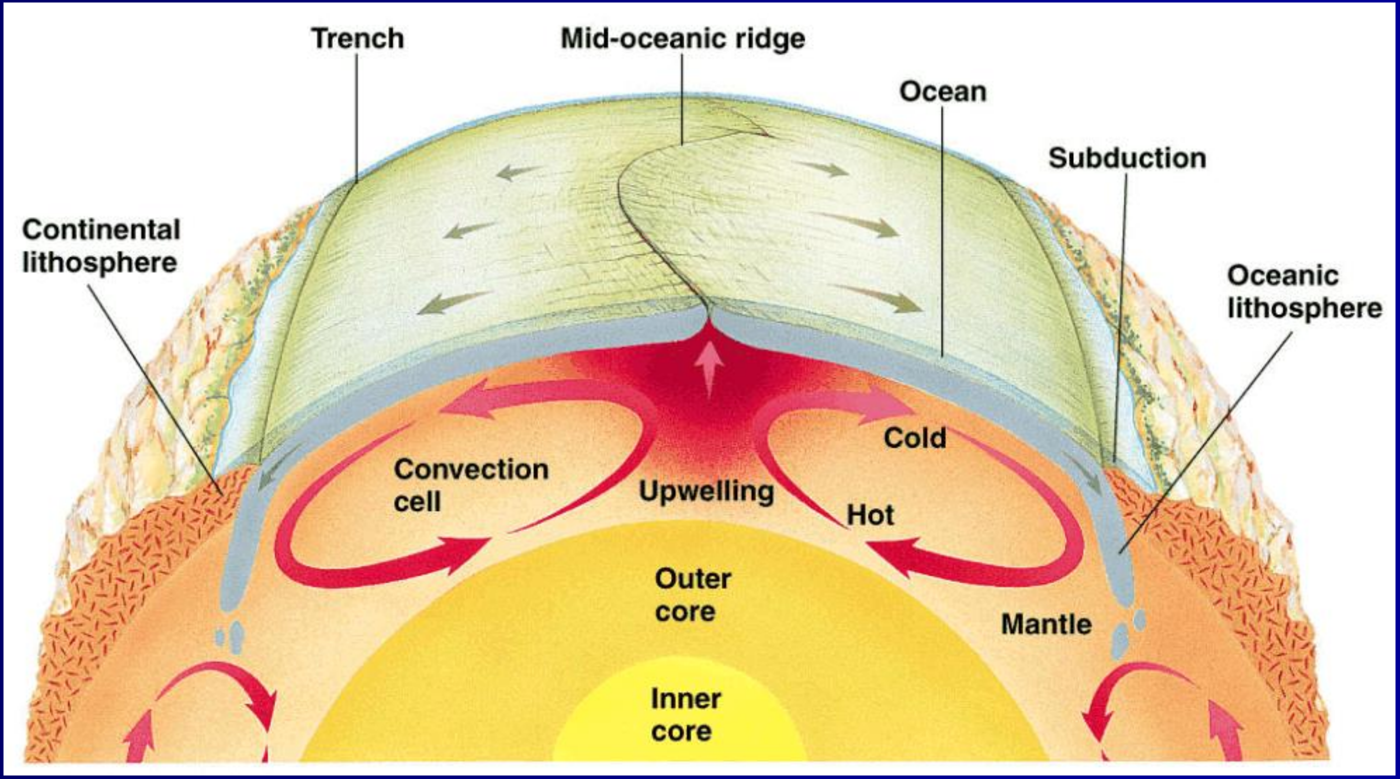


Fig. 2.7. Internal Structure of the Earth (Diagrammatic-not to scale)

Plate Tectonics

- Lithosphere is broken into individual pieces called plates



- Plates move over the asthenosphere
  – as a result of underlying *convection cells*

PLATE TECTONICS:

Pieces of a Jig-saw puzzle of both continent and ocean often reinforced by geological and bio-geographical considerations.

In accordance to sea floor spreading from oceanic ridges the Continents move aside

If one ocean grows the adjacent ocean should shrink but it is not the case in some plate.

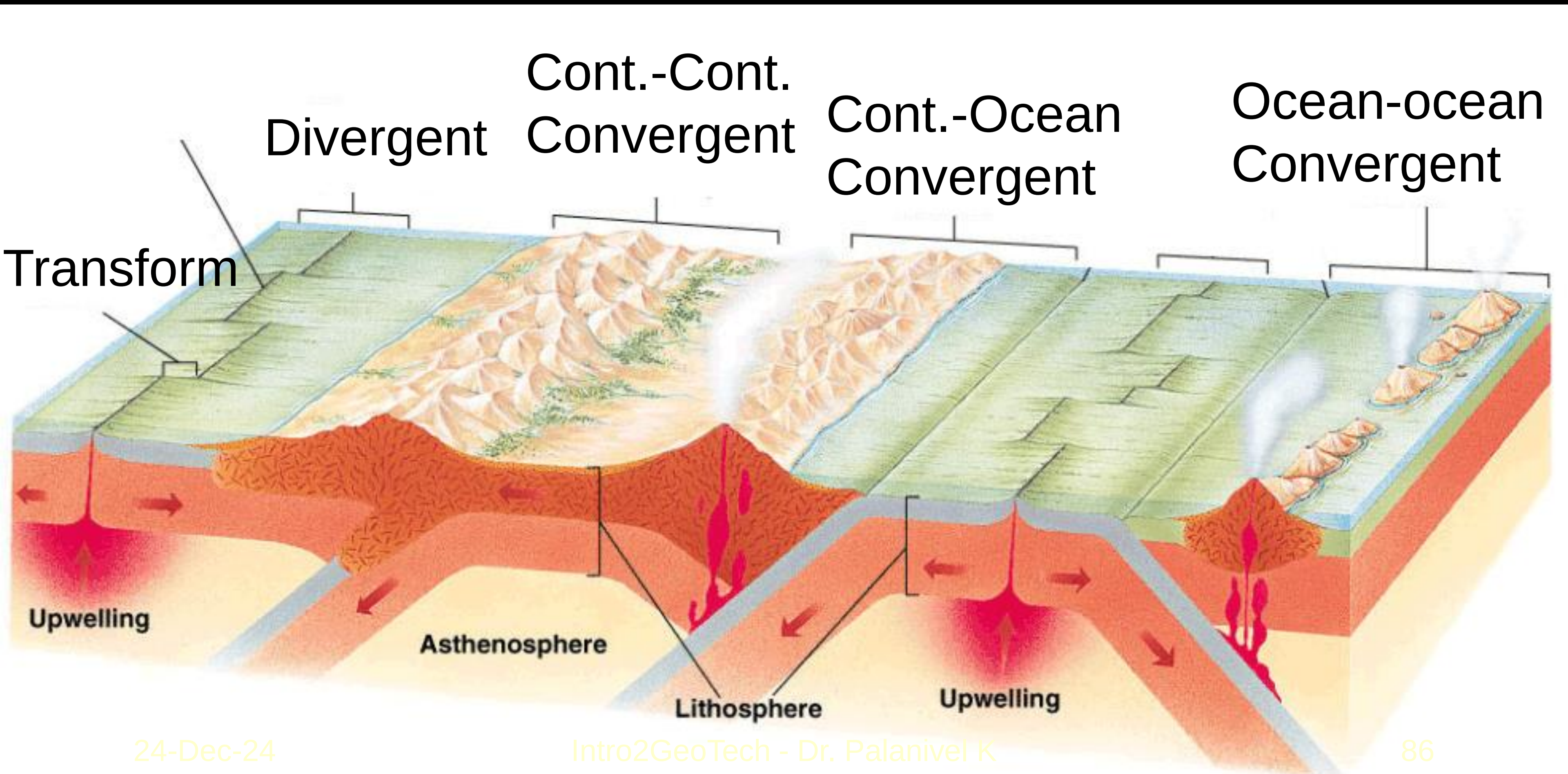
This is due to subduction at the plate collision site.

Plate Tectonic Theory

- at plate boundaries
  - volcanic activity occurs
  - earthquakes occur
- movement at plate boundaries
  - plates diverge
  - plates converge
  - plates slide sideways past each other

Plate Tectonic Theory

- types of plate boundaries



Several lithospheric plates are recognized on Earth's surface

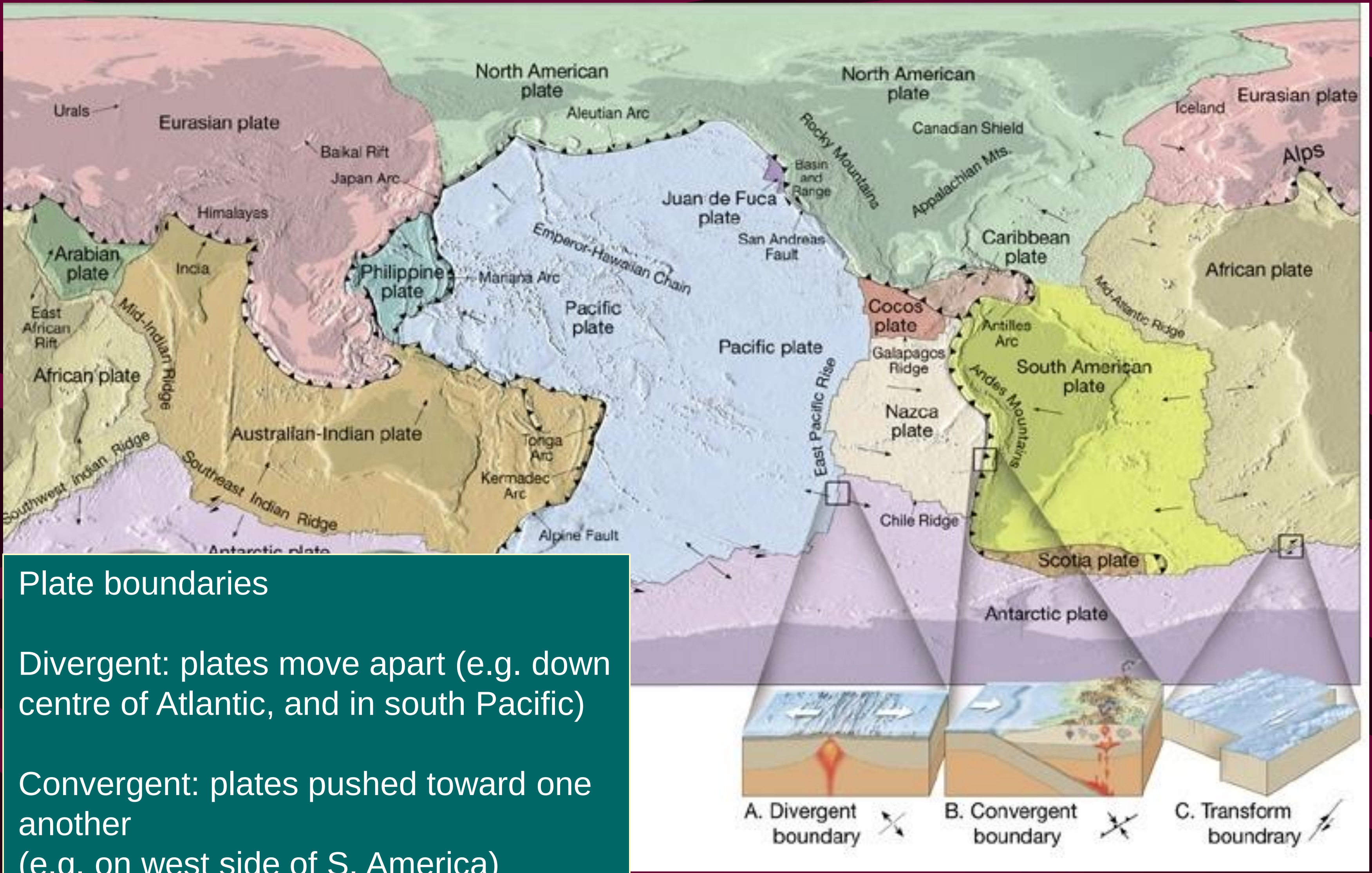


Plate boundaries

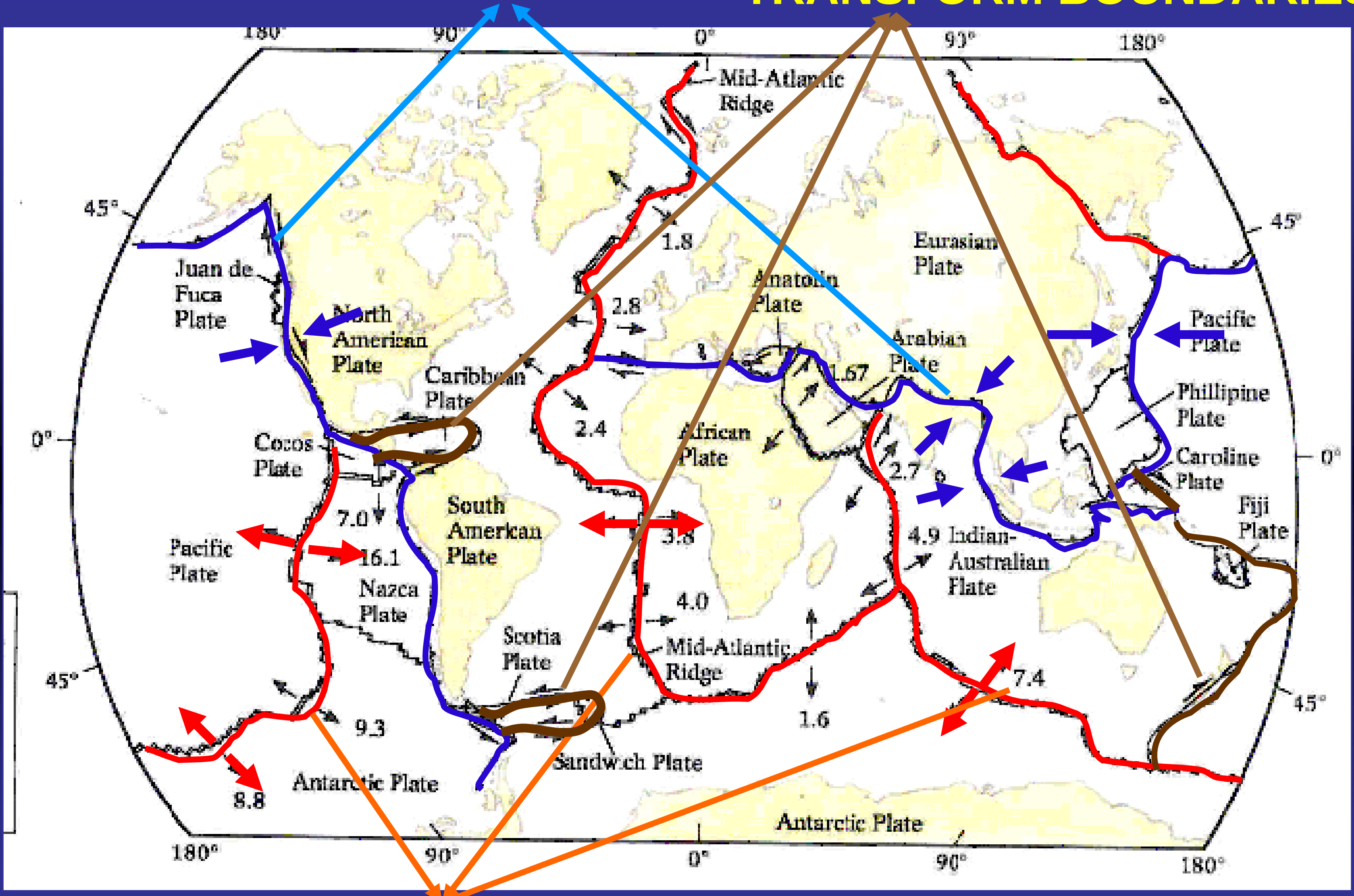
Divergent: plates move apart (e.g. down centre of Atlantic, and in south Pacific)

Convergent: plates pushed toward one another
(e.g. on west side of S. America)

Transform: plates slide alongside one another (e.g. San Andreas fault)

CONVERGENT BOUNDARIES

TRANSFORM BOUNDARIES



DIVERGENT BOUNDARIES

Table 2–1 • CHARACTERISTICS AND EXAMPLES OF PLATE BOUNDARIES

TYPE OF BOUNDARY	TYPES OF PLATES INVOLVED	TOPOGRAPHY	GEOLOGIC EVENTS	MODERN EXAMPLES
Divergent	Ocean-ocean	Mid-oceanic ridge	Sea-floor spreading, shallow earthquakes, rising magma, volcanoes	Mid-Atlantic ridge
	Continent-continent	Rift valley	Continents torn apart, earthquakes, rising magma, volcanoes	East African rift
Convergent	Ocean-ocean	Island arcs and ocean trenches	Subduction, deep earthquakes, rising magma, volcanoes, deformation of rocks	Western Aleutians
	Ocean-continent	Mountains and ocean trenches	Subduction, deep earthquakes, rising magma, volcanoes, deformation of rocks	Andes
	Continent-continent	Mountains	Deep earthquakes, deformation of rocks	Himalayas
Transform	Ocean-ocean	Major offset of mid-oceanic ridge axis	Earthquakes	Offset of East Pacific rise in South Pacific
	Continent-continent	Small deformed mountain ranges, deformations along fault	Earthquakes, deformation of rocks	San Andreas fault

FIGURE 12.5 The best fit between continents occurs along the continental slope at a depth of 2000 m.

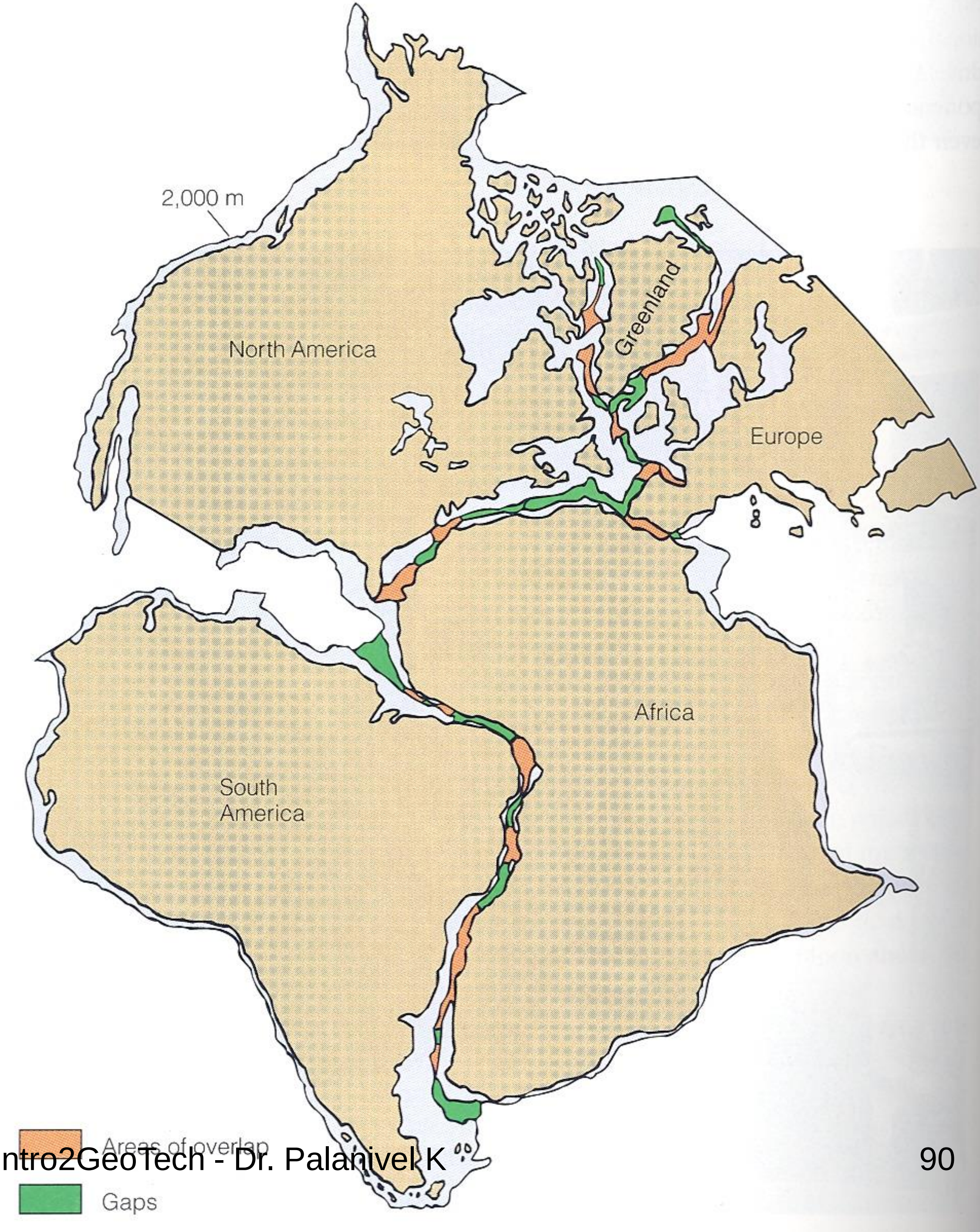


FIGURE 12.6 Marine, nonmarine, and glacial rock sequences of Pennsylvanian to Jurassic age are nearly the same for all Gondwana continents. Such close similarity strongly suggests that they were joined together at one time. The range indicated by G is that of the *Glossopteris* flora.

outward from their central area of accum... the sea.

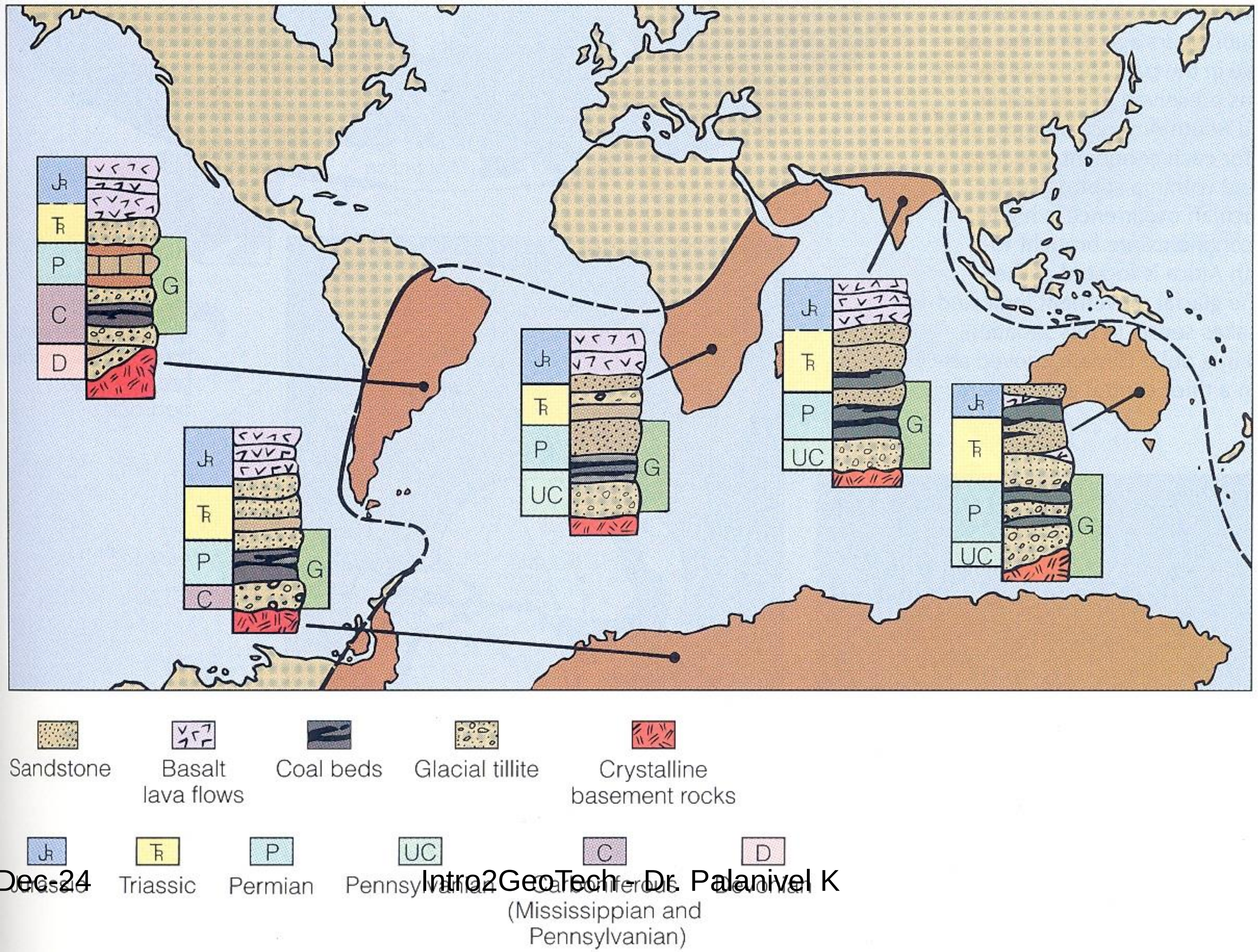
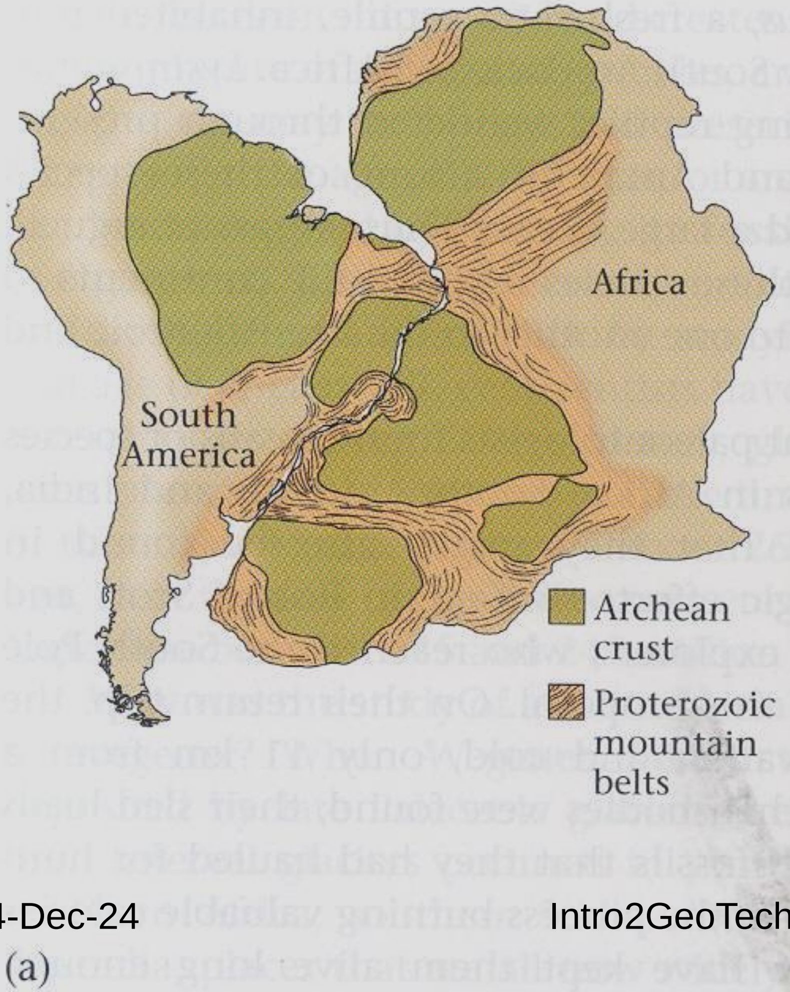
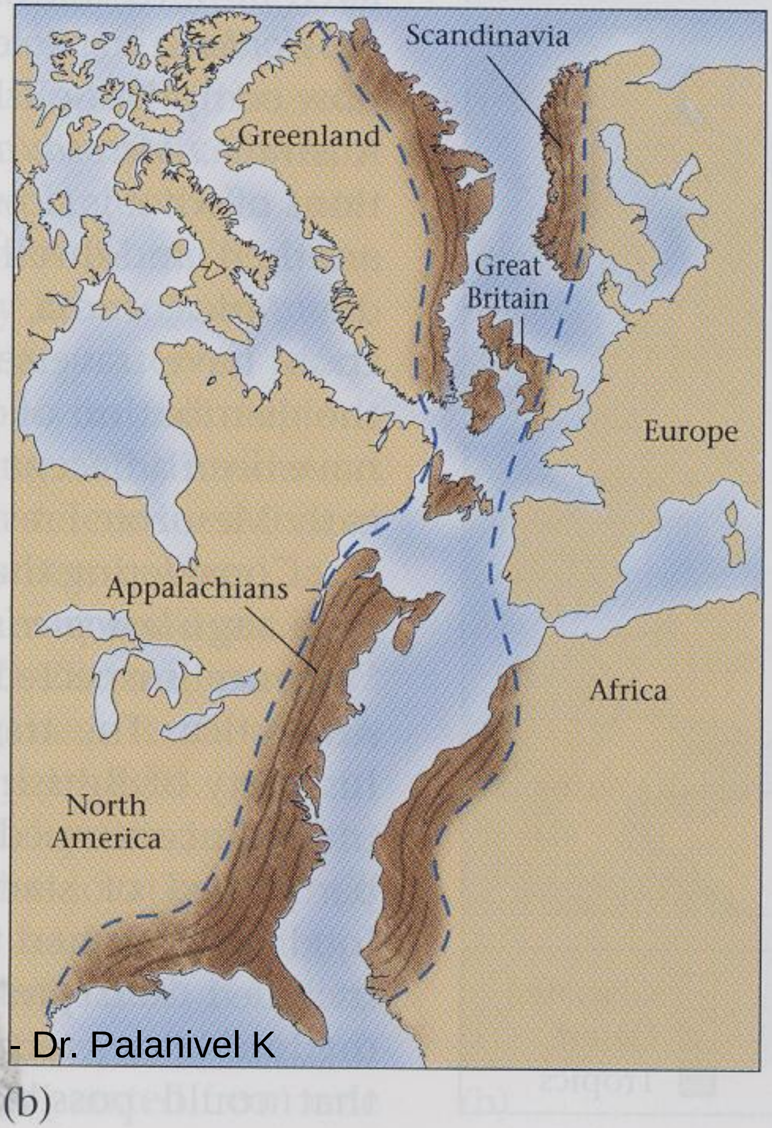


FIGURE 2.6 (a) Distinctive areas of rock units on South America link with those on Africa, as if they were once connected and later broke apart. (b) If the continents are returned to their positions in Pangaea by closing the Atlantic, mountain belts of the Appalachians lie adjacent to similar-age mountain belts in Greenland, Great Britain, Scandinavia, and Africa.





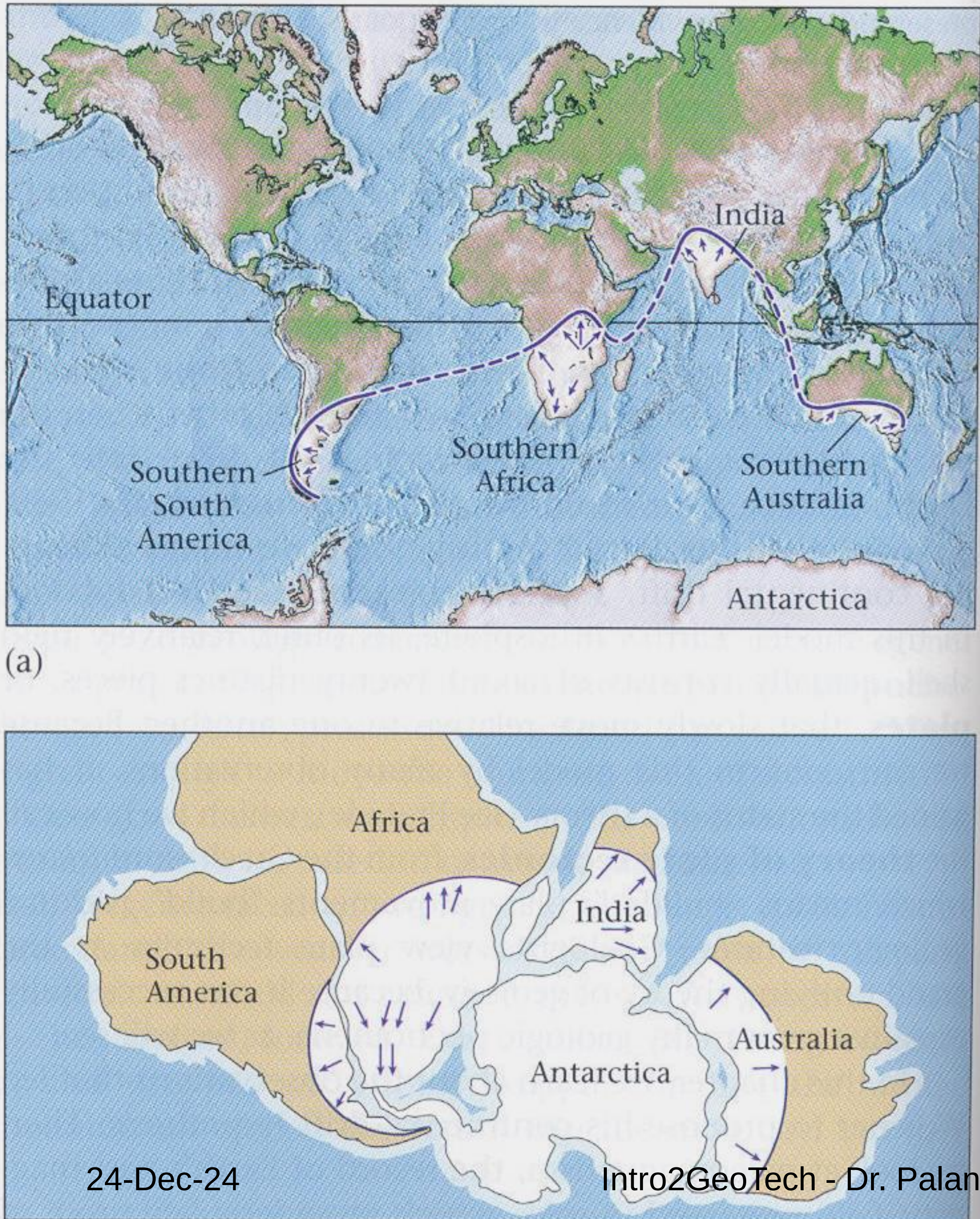


FIGURE 2.3 (a) The distribution of late Paleozoic glacial deposits on a map of the present-day Earth. The arrows indicate the orientation of striations. (b) The distribution of these glacial deposits on a map of the southern portion of Pangaea. Note that the glaciated areas fit together to define a polar ice cap.

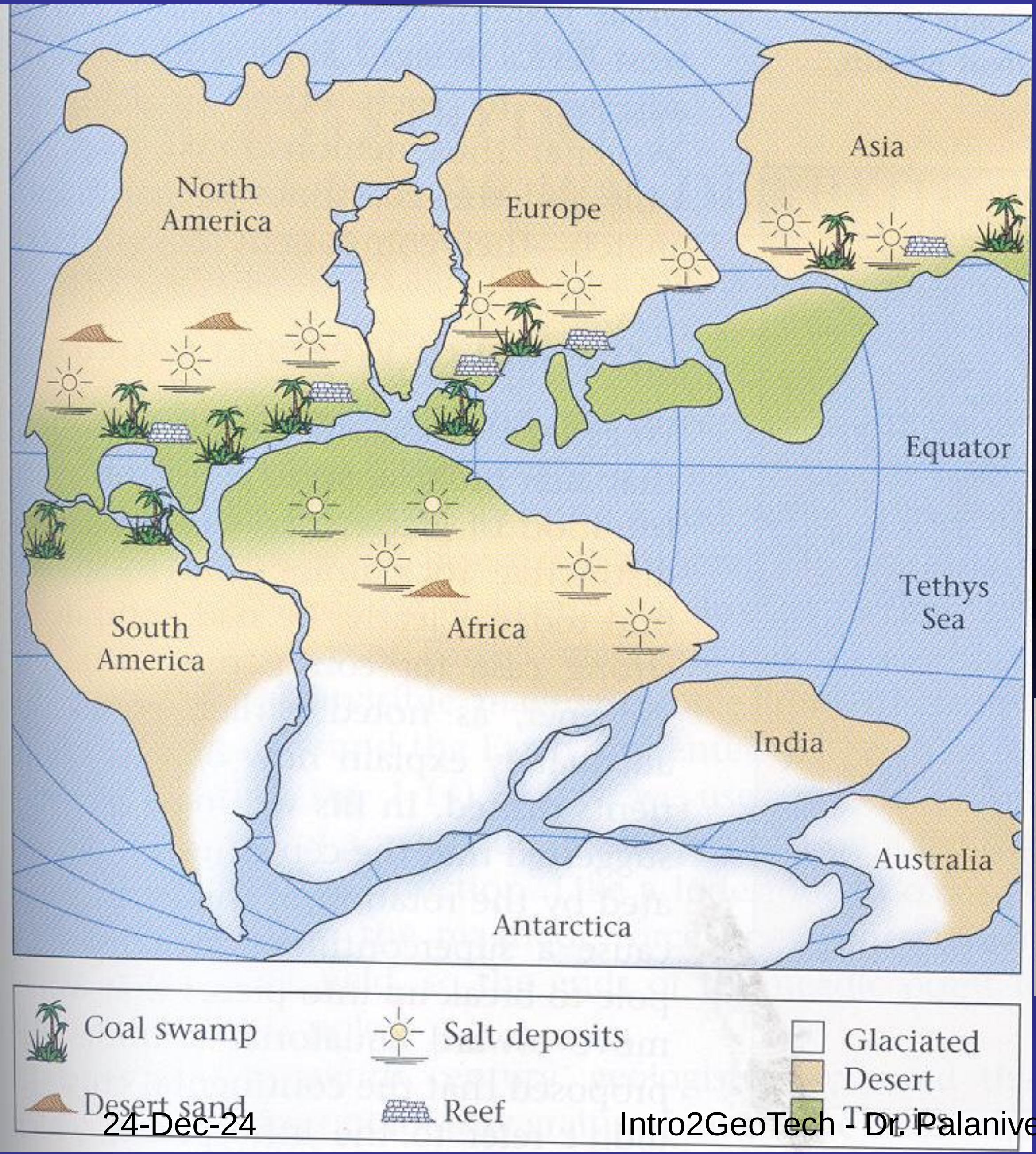


FIGURE 2.4 Map of Pangaea, showing the distribution of coal deposits and reefs (indicating tropical environments), and sand-dune deposits and salt deposits (indicating subtropical environments). Note how deposits now on different continents align in distinct belts.

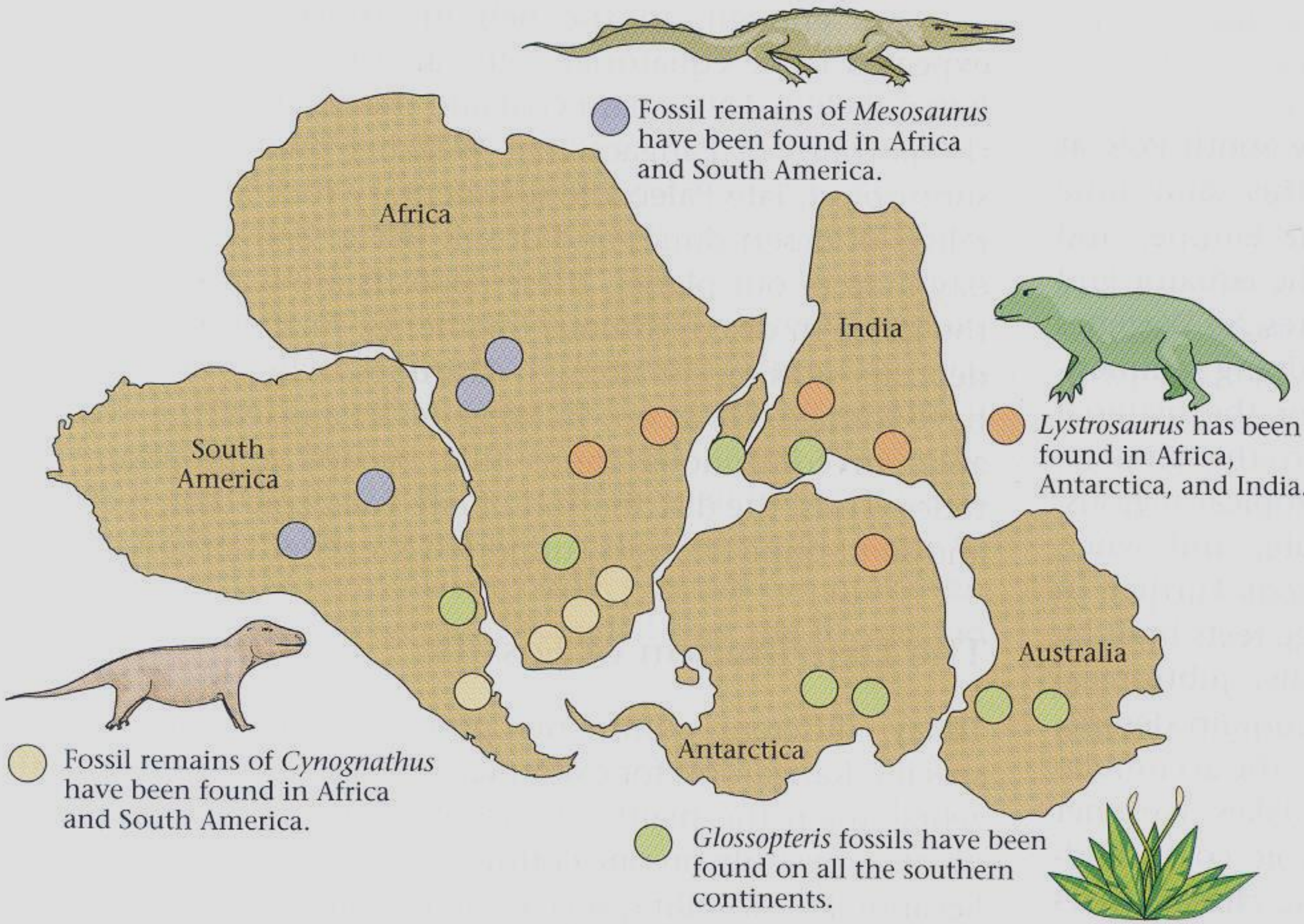
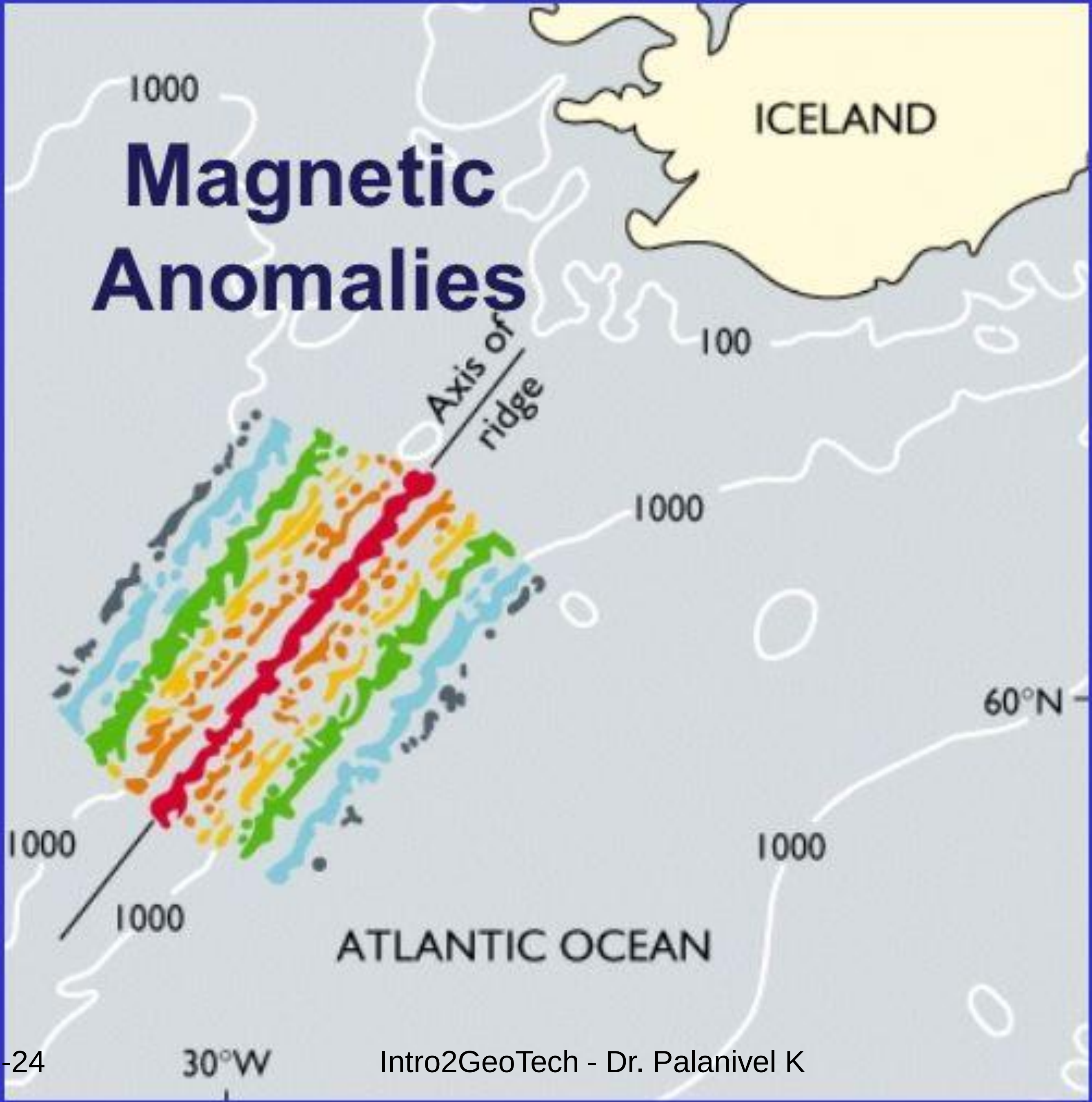
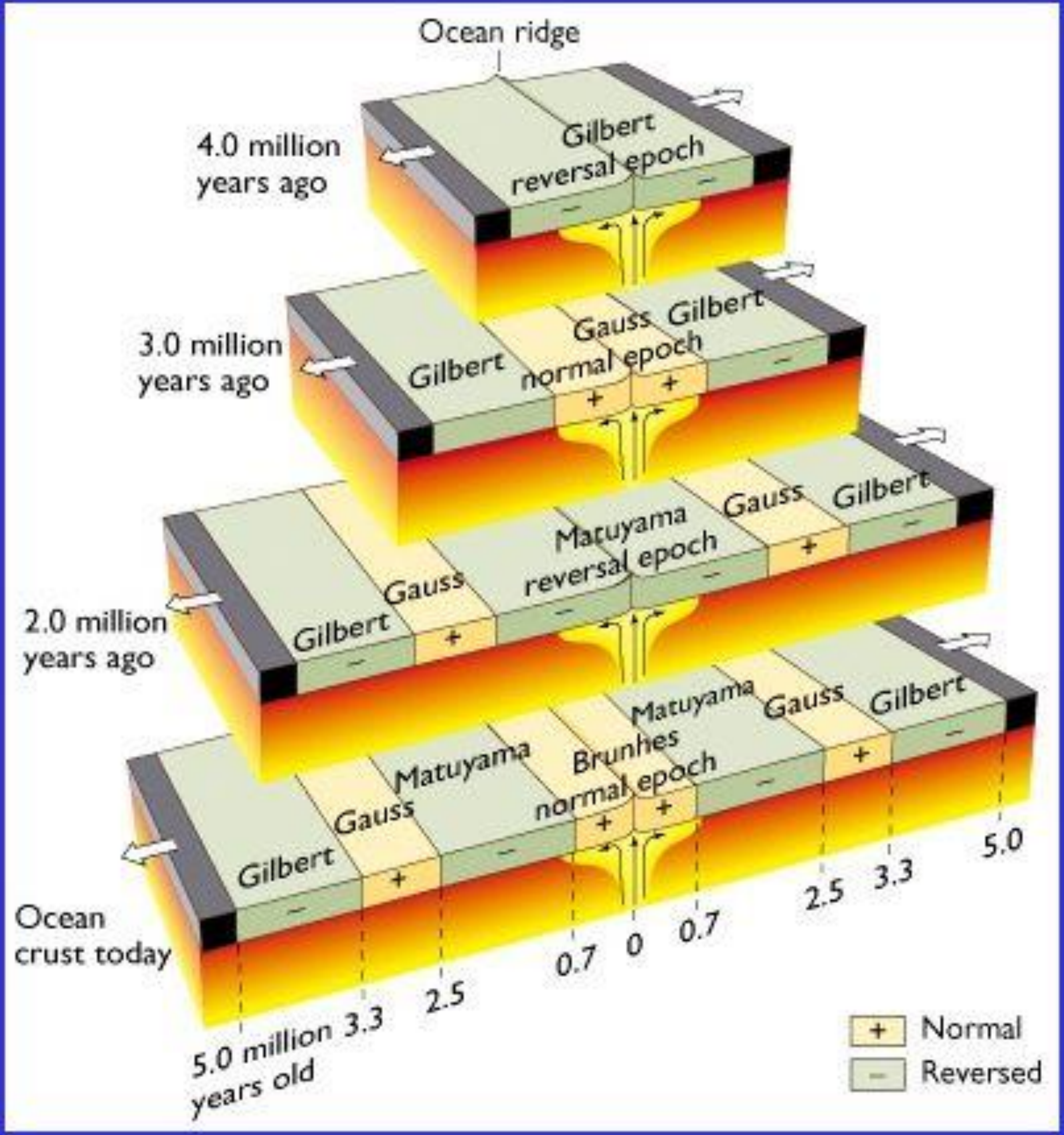


FIGURE 2.5 This map shows the distribution of terrestrial (land-based) fossil species. Note that creatures like *Lystrosaurus* could not have swum across the Atlantic to reach Africa.

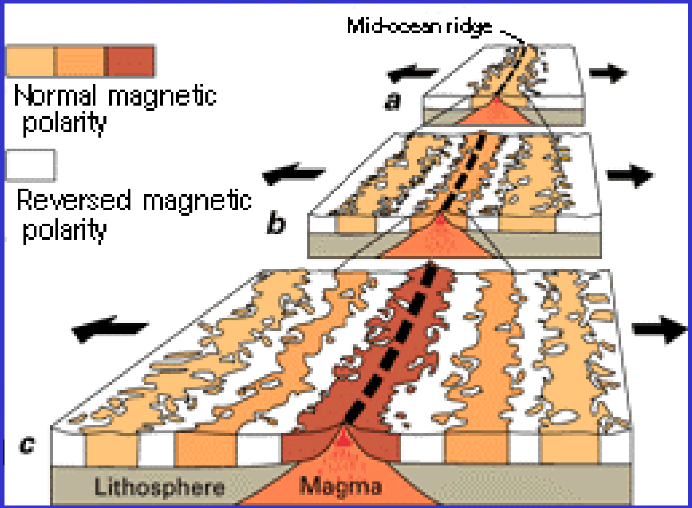


Magnetic
Anomalies
ICELAND
1000
100
Axis of ridge
1000
60°N
1000
1000
1000
ATLANTIC OCEAN
30°W

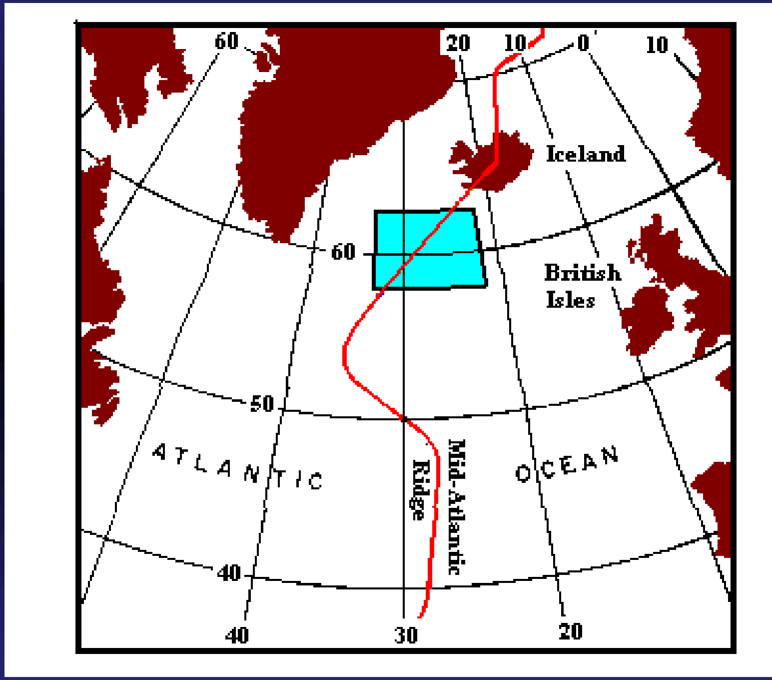
Fig. 20.9

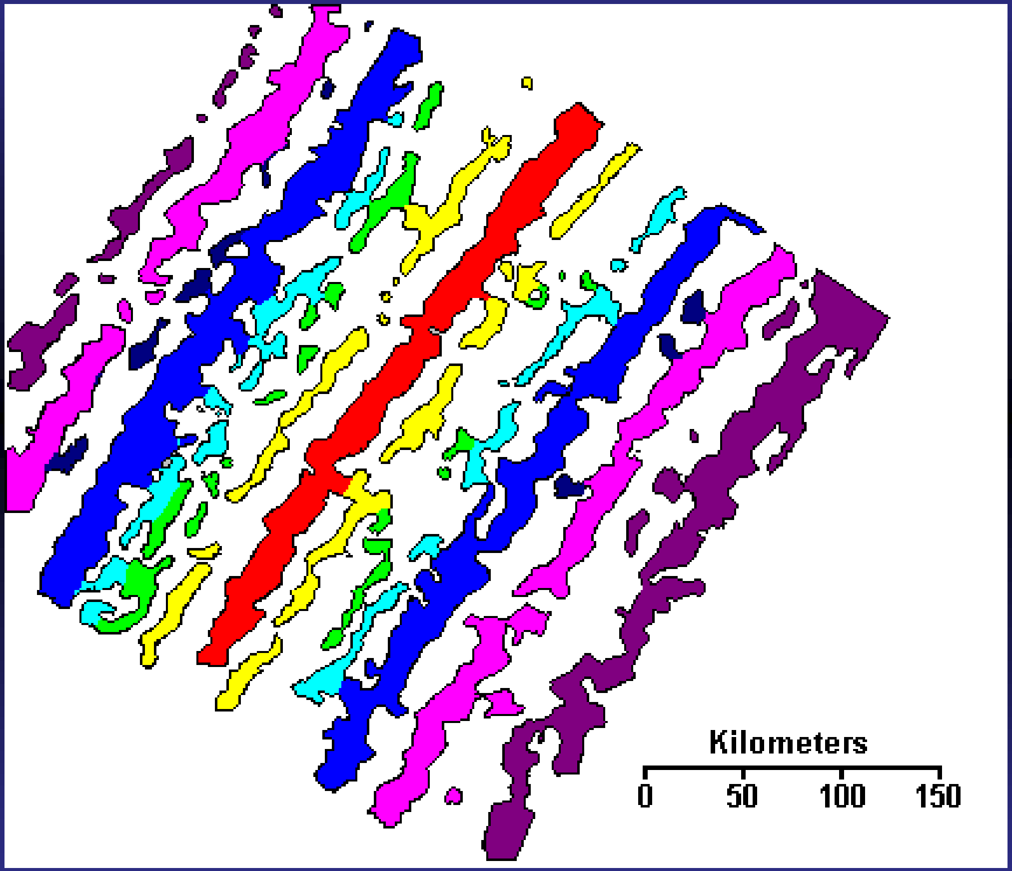


Formation of Magnetic Anomalies



Discovery of Sea-Floor Spreading





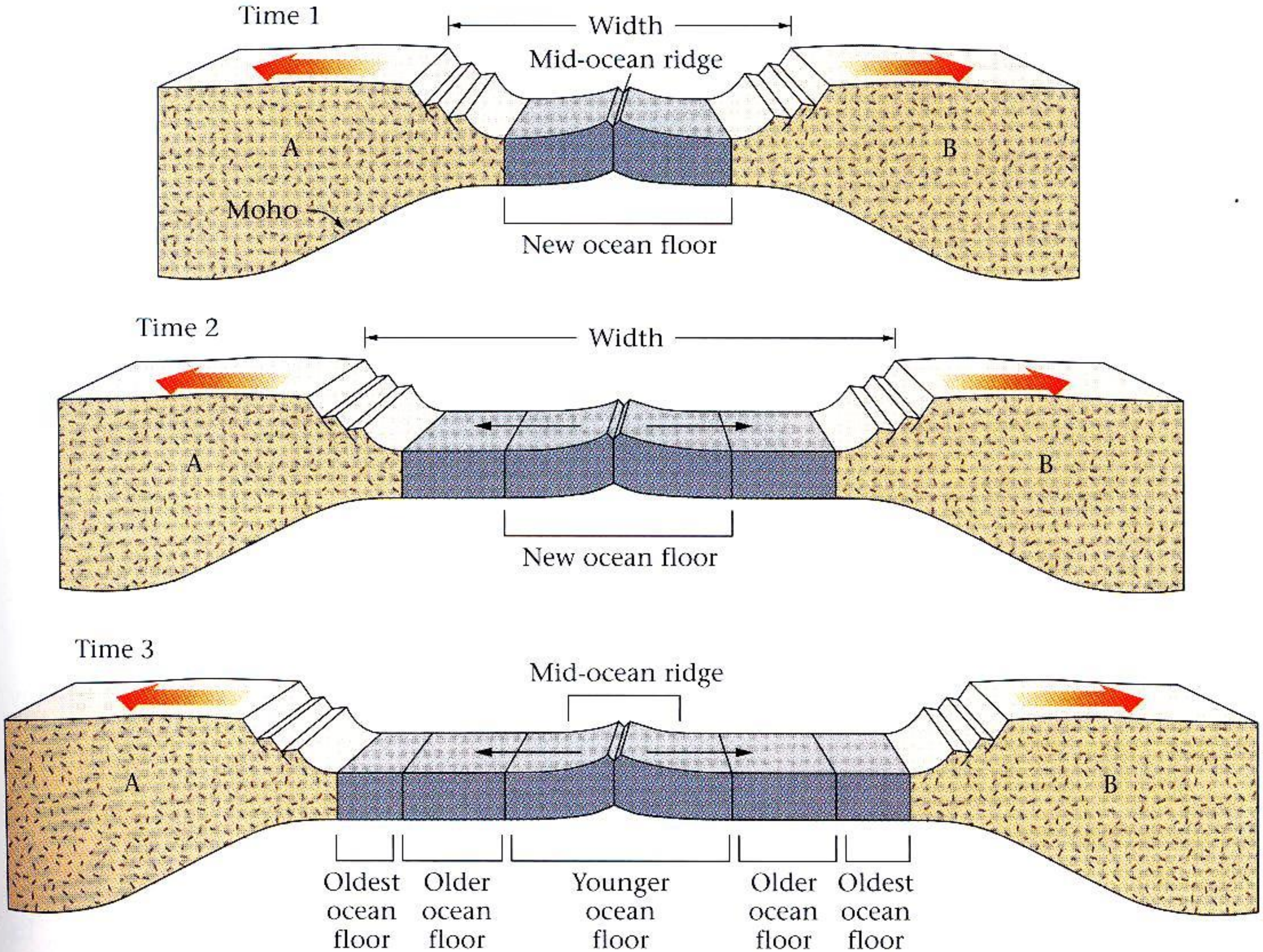


FIGURE 2.33 These sketches depict successive stages in sea-floor spreading along a divergent boundary (mid-ocean ridge); only the crust is shown. The top figure represents an early stage of the process, after the mid-ocean ridge formed but before the ocean grew very wide. With time, as seen in the next two figures, the ocean gets wider and continent A drifts way from continent B. Note that the youngest ocean crust lies closest to the ridge.

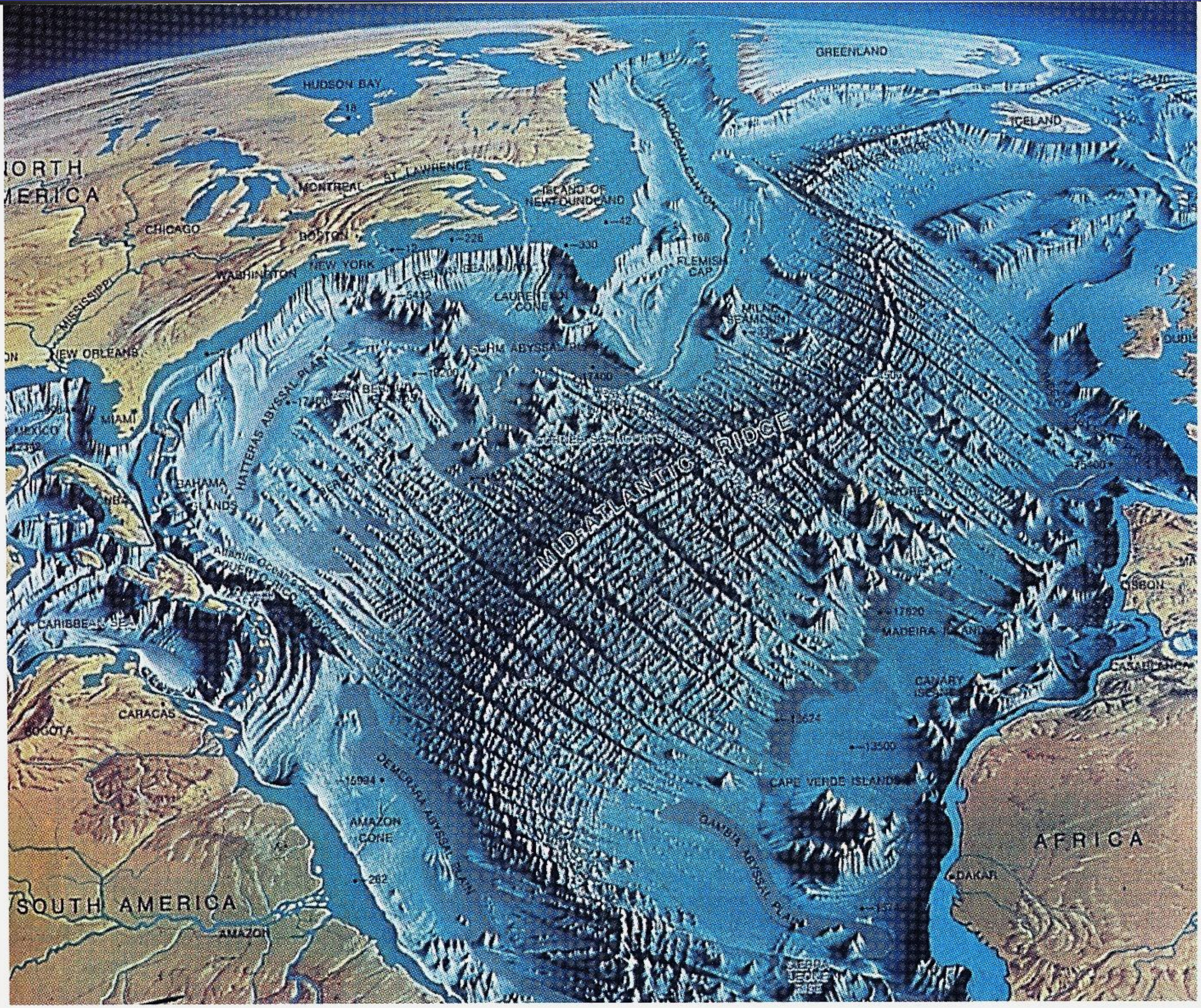
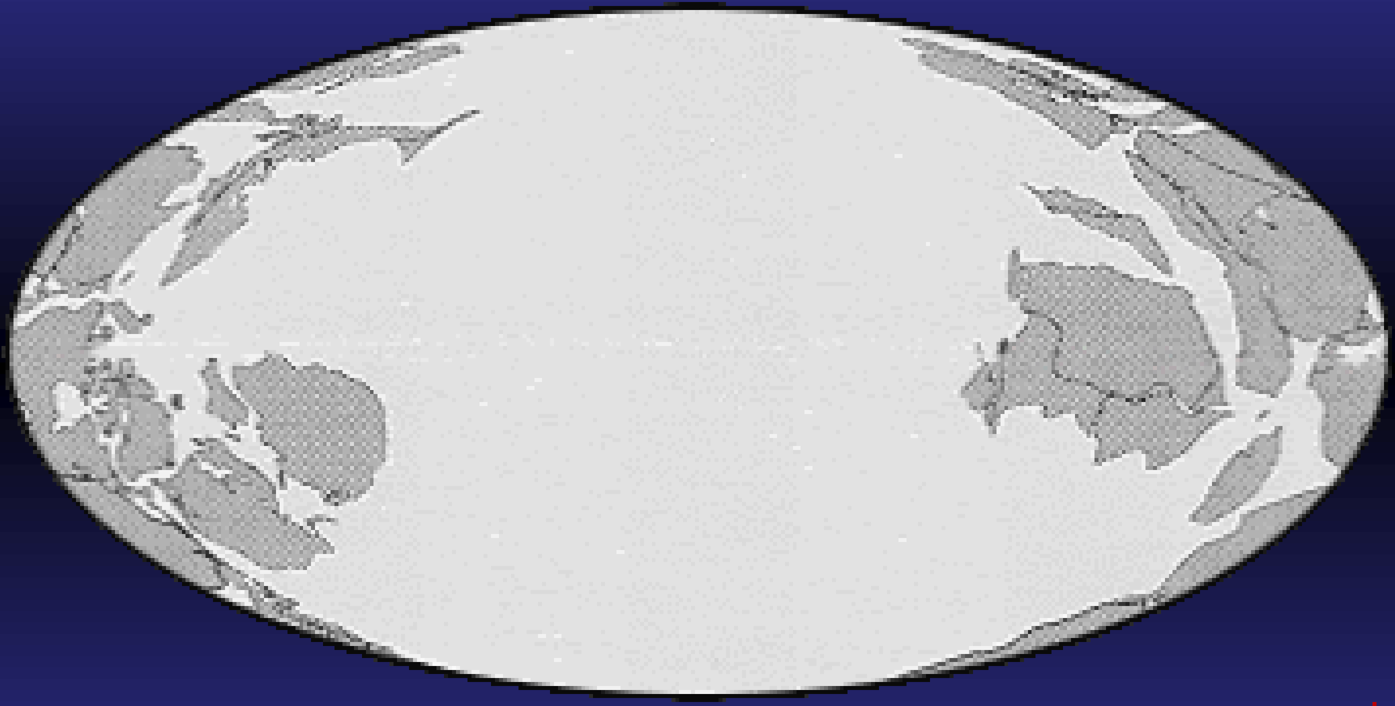


FIGURE 12.11 Artistic view of what the Atlantic Ocean basin would look like without water. The major feature is the Mid-Atlantic Ridge. *(Photo courtesy of ALCOA.)*

Continental Drift



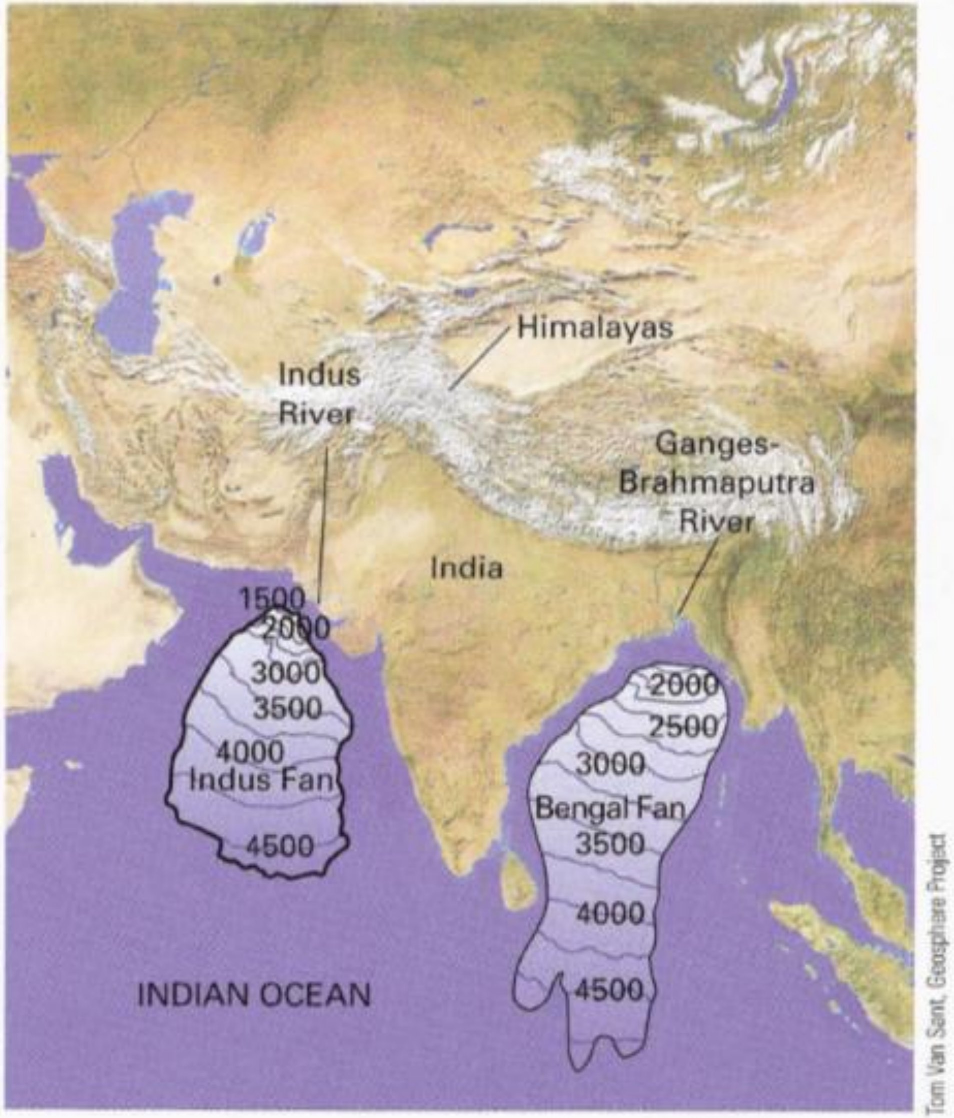


FIGURE 11.16 The Indus River and the Ganges-Bramaphutra River have transported millions of cubic kilometers of sediment eroded from the Himalayas to the Indian Ocean. Note that the combined area for the Bengal and Indus fans is larger than the entire subcontinent of India!

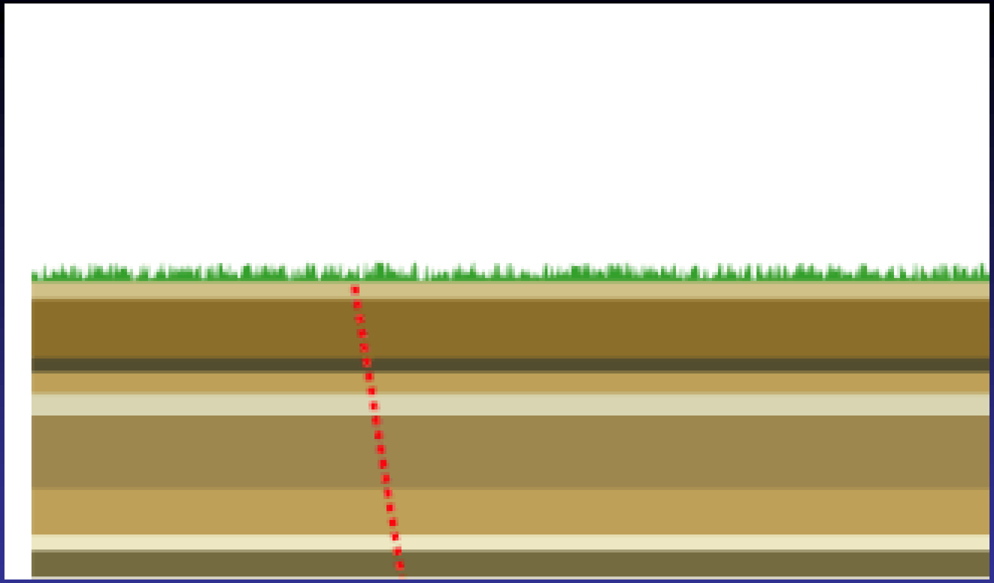
Mountain building activities – origin of rivers – Physiography of the Earth

The mountains formed due to

- Tectonic / Plate Tectonic activities such as emergence and subsidence processes are called as Block mountains
- volcanic eruptions - Volcanic mountains,
- removal of surrounding softer material around a hard / dense crust and acquiring relief as mountains -

Based on the nature of formation, they are termed as :

- ❖ volcanic,
- ❖ fold,
- ❖ plateau,
- ❖ fault-block and
- ❖ dome mountains.

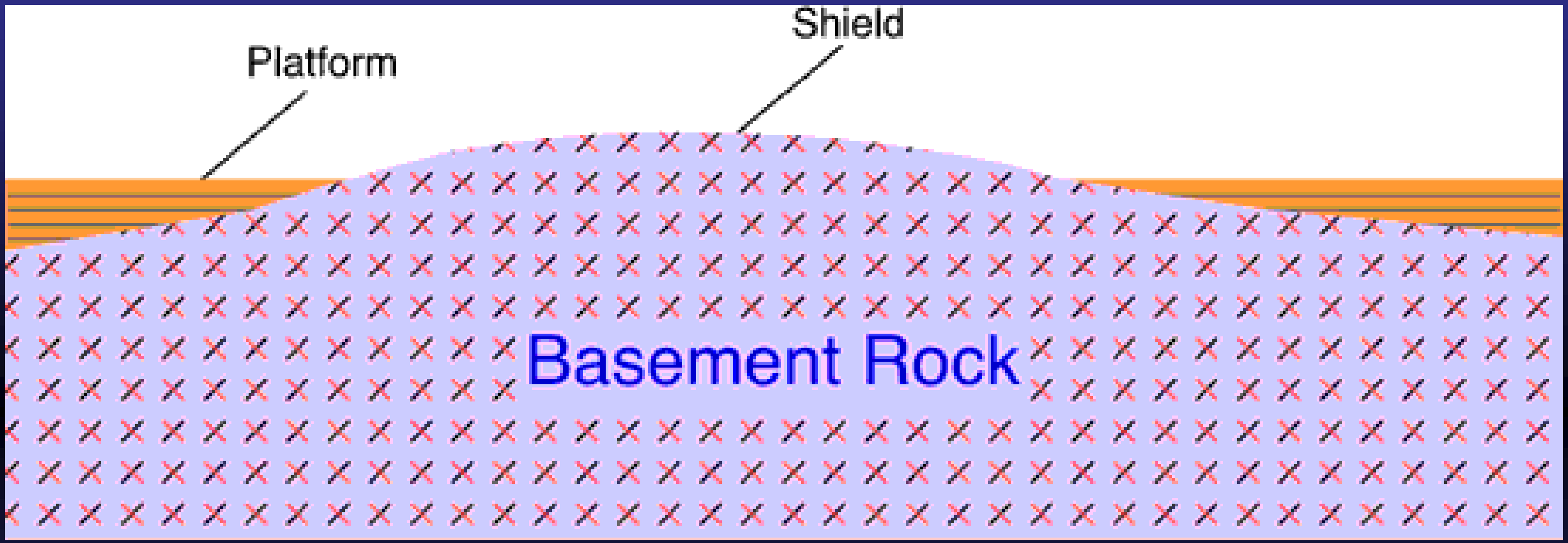


Origin of Rivers – Meteoric water once reaches the Earth's surface in multiple forms, the water interacts with the variety of terrain features and thus partly evaporated and return to the atmosphere, partly infiltrated & percolated inside the Earth into the subsurface and the remaining water gets collected and started flowing along the lower relief areas due to gravity as drainages. Several such drainages merge at the lower levels and increases its dimension to form rivulets and then as rivers.

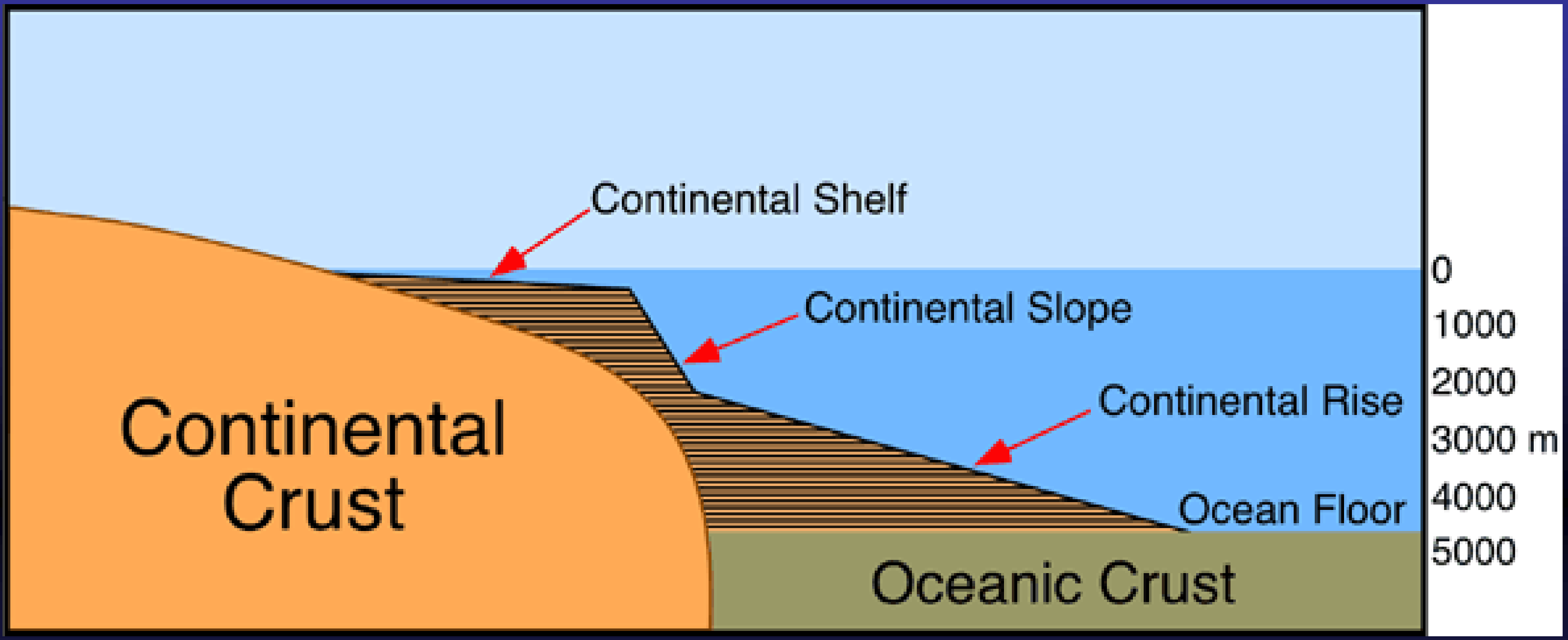
There are rivers on the Earth fed not only by rain water, but also by Glacier melt and Springs (from the Groundwater).

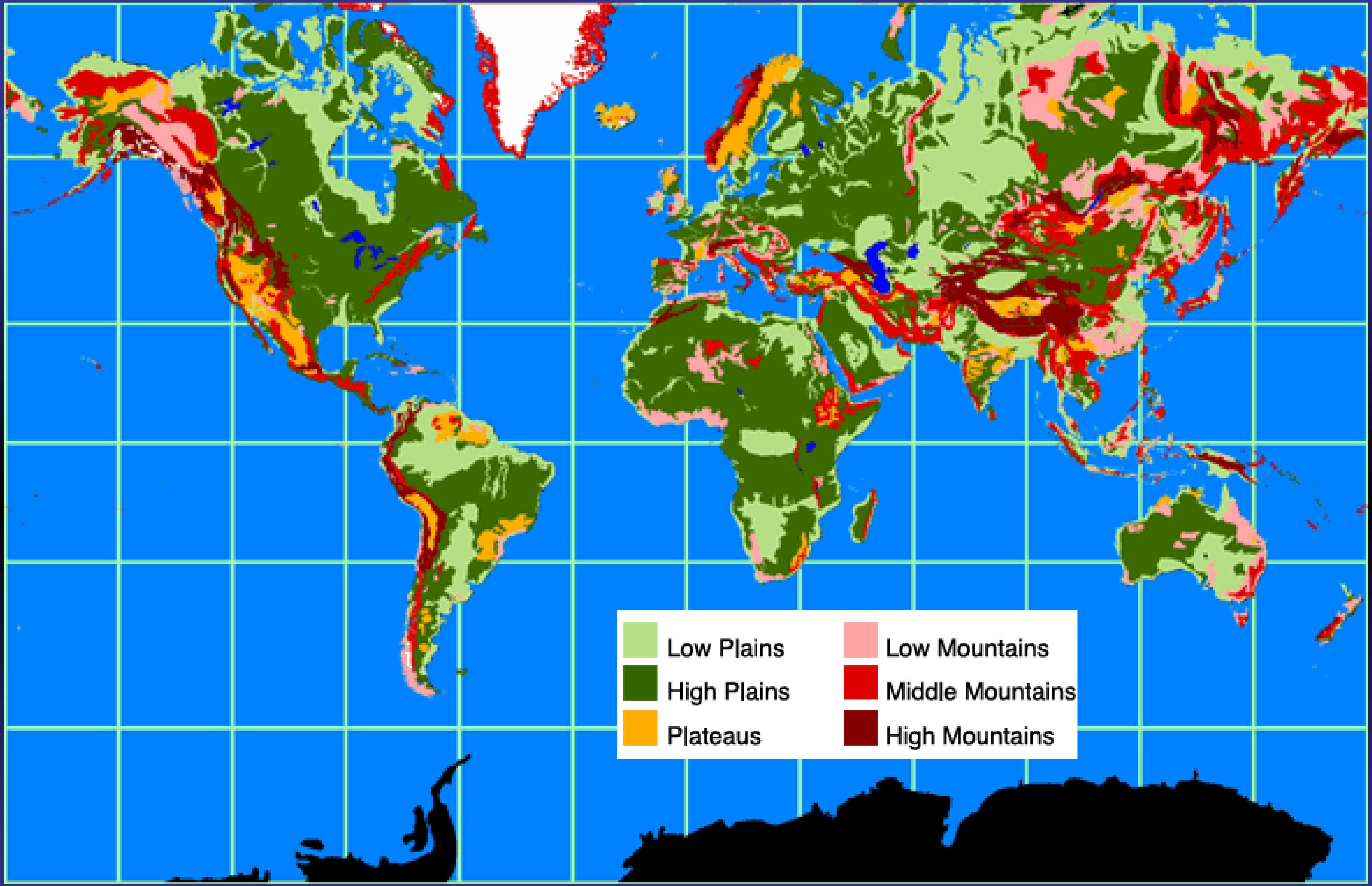
The Himalayan rivers are perennial – due to rainfall and ice melt

The rivers in the plains are rain fed, and thus they are ephemeral.



Basement rock that is exposed at the Earth's surface is called **shield**. The shields extend for thousands of kilometers and dip ever so slightly from a slightly elevated center. Layers of younger sedimentary strata up to 2000 meters deep cover most of the basement rock. These sedimentary deposits are sometimes called the **platform** of the continents. The deposits making up the platform were laid down in shallow seas in repeated episodes over the last 600 million years. The platform and the basement rock together form a **craton**.


Continental Shelf
Continental Slope
Continental Rise
Ocean Floor
Continental Crust
Oceanic Crust
0
1000
2000
3000 m
4000
5000


Low Plains
High Plains
Plateaus
Low Mountains
Middle Mountains
High Mountains