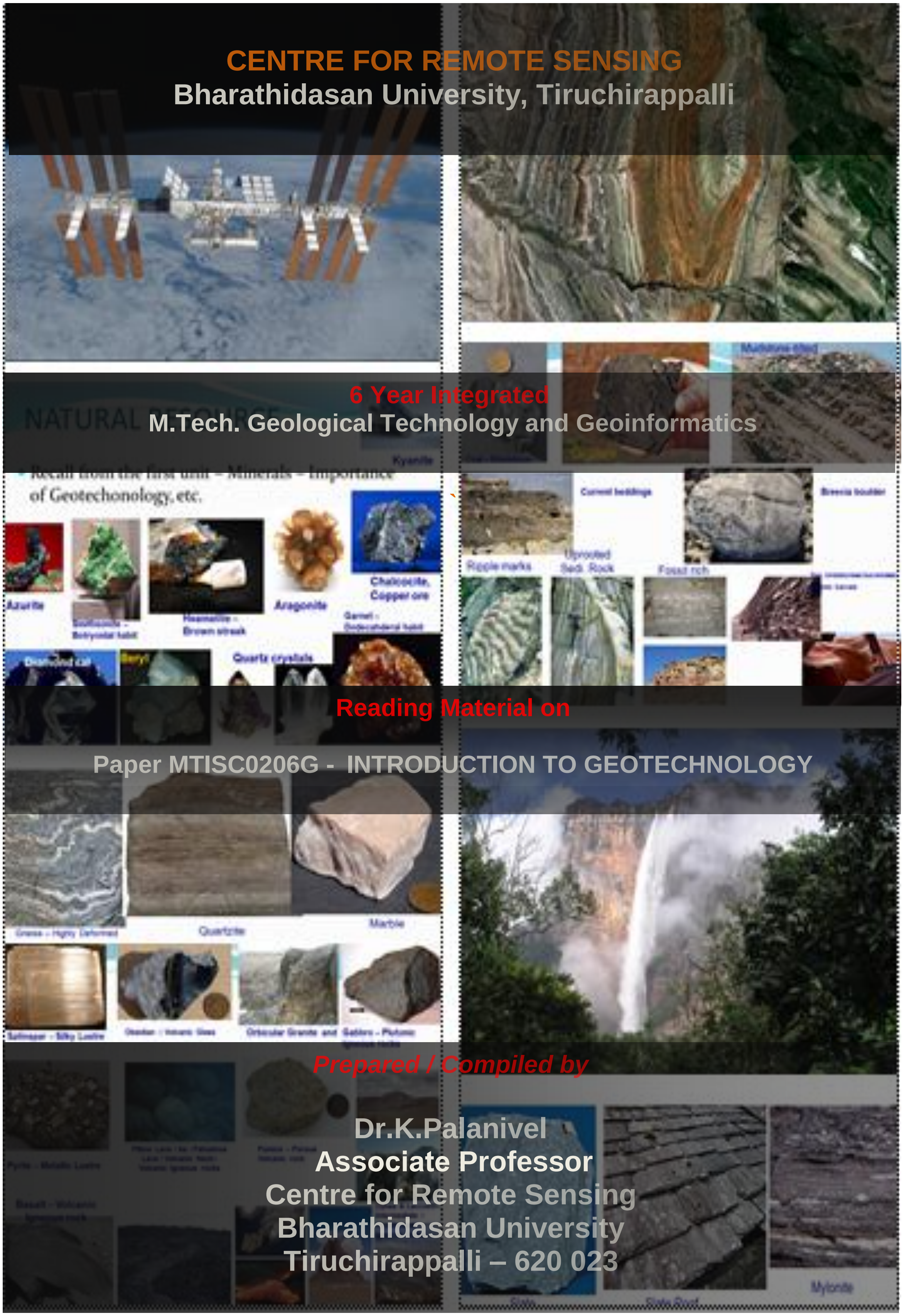

CENTRE FOR REMOTE SENSING

Bharathidasan University, Tiruchirappalli

6 Year Integrated

M.Tech. Geological Technology and Geoinformatics

Reading Material on

Paper MTISC0206G - INTRODUCTION TO GEOTECHNOLOGY

Prepared / Compiled by

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Paper MTISC0206G - INTRODUCTION TO GEOTECHNOLOGY --- 3credits

1. **Earth System Processes:** **6 hrs.**

   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:** **12 hrs.**

   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:** **12 hrs.**

   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:** **12 hrs.**

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

5. **Geoinformatics:** **6 hrs.**

   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.

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Unit-1 EARTH SYSTEM PROCESSES

Earthsciences

GEOTECHNOLOGY - Definition

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

Geologist's Discipline - Branches of Earth Sciences

- 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.**

<u>Branches of Geosciences</u>:

- Geology, Meteorology, Oceanography
- 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.

There are several disciplines, subdisciplines and interdisciplines studied under Earth Science, Geoscience, Science of Earth/Geology. Geologists may concentrate their studies or research in one or more of the following disciplines / interdisciplines:

1. **Agrogeology** is the study of minerals of importance to farming and horticulture, especially with regards to soil fertility and fertilizer components. These minerals are usually essential plant nutrients and are referred to as agrominerals.
2. <u>Astronomy:</u>

3. Biogeochemistry suggested geophysiological processes were responsible for the development of the Earth through a succession of phases where with the geosphere (of inanimate matter) develops into the biosphere (of biological life).
4. Cave Geology: Geology of caves, caverns, and formations found therein
5. Cosmology:
6. Climatology:
7. Crystallography:
8. Coal Geology:
9. Economic geology: the study of ore genesis, and the mechanisms of ore creation,
10. Geostatistics.
11. Engineering Geology:
12. **Geoarchaeology** is a sub-field of archaeology which uses the techniques and subject matter of geography and other earth sciences to examine topics which inform archaeological knowledge and thought.
13. **Geobiology** is Broadly defined, as an interdisciplinary field of scientific research that explores interactions between the biosphere and the lithosphere and/or the atmosphere. Investigators from numerous fields are involved in **geobiologic** research, including, but not limited to, such disciplines as: palaeontology, palaeobiology, microbiology, mineralogy, biochemistry, sedimentology, genetics, physiology, geochemistry (organic and inorganic), and atmospheric science. One major subdiscipline of geobiology is **geomicrobiology**, an area of study that focuses on investigating the interactions between microbes and minerals. Another related area of research is astrobiology, an interdisciplinary field that uses a combination of **geobiological** and planetary science data to establish a context for the search for life on other planets.

14. Geochemistry: the study of the chemical makeup and behaviour of rocks, and the study of the behaviour of their minerals.

15. Geochronology: the study of isotope geology specifically toward determining the date within the past of rock formation, metamorphism, mineralization and geological events (notably, meteorite impacts). **Geochronology** is the science of determining the absolute age of rocks, fossils, and sediments, within a certain degree of uncertainty inherent within the method used. A variety of dating methods are used by geologists to achieve this.

16. **Geoforecasting** is the science of predicting the movement of tectonic plates and the future climate, shape, and other geological elements of the planet.

17. Geomorphology: **Geomorphology** (from Greek: γη, *ge*, "earth"; μορφή, *morfé*, "form"; and λόγος, *logos*, "knowledge") is the study of landforms, including their origin and evolution, and the processes that shape them. The underlying question is: Why do landscapes look the way they do? Geomorphologists seek to understand landform history and dynamics, and predict future changes through a combination of field observation, physical experiment, and numerical modeling. The discipline is practiced within geology, geodesy, geography, archaeology, and civil and environmental engineering. Early studies in geomorphology are the foundation for pedology, one of two main branches of soil science.

18. **Geomechanics** (Greek prefix *geo* meaning earth; and mechanics) is the study of the behavior of soil and rock. The two main disciplines of geomechanics are soil mechanics and rock mechanics. The former deals with the behaviour of soil from a small scale to a landslide scale. The latter deals with issues in geosciences related to rock mass characterization and rock mass mechanics, such as tunneling and earth drilling. Some of geomechanics relates to geotechnical engineering. Modern developments relate to seismology, continuum mechanics, discontinuum mechanics, and transport phenomena.

19. **Geophysiology** (*Geo*, earth + *physiology*, the study of living bodies) is the study of interaction among living organisms on the Earth operating under the hypothesis that the Earth itself acts as a single living organism (Gaia).

20. **Geophysics -** the quantitative observation of Earth's physical properties, Study of Seismic - Electrical – Gravity – Magnetic - Radiometric properties, Airborne geophysical survey, Well logging, etc.

    - **Geodesy -** measurement of the Earth
    - **Tectonophysics -** physical processes that cause and result from plate tectonics
    - **Geodynamics -** modes of transport deformation within the Earth: rock deformation, mantle flow and convection, heat flow, lithosphere dynamics
    - **Seismology -** earthquakes and the propagation of elastic waves through the Earth
    - **Mathematical Geophysics -** development and applications of mathematical methods and techniques for the solution of geophysical problems

21. **Geostatistics** explains not only its applications within Geographic Information Systems but also the numerous applications of mathematical analysis on varied spatial datasets, the most prominent being a digital elevation model, from which any number of analyses may be derived. Geostatistics is also applied in varied branches of human geography, particularly those involving the spread of disease (epidemiology), the practice of commerce and military planning (logistics), and the development of efficient spatial networks.

22. **Geotechnical engineering** is the branch of civil engineering concerned with the engineering behavior of earth materials. Geotechnical engineering

includes investigating existing subsurface conditions and materials; assessing risks posed by site conditions; designing earthworks and structure foundations; and monitoring site conditions, earthwork and foundation construction.

23. **Geosynthetics** is the term used to describe a range of generally synthetic products used to solve geotechnical problems. The term is generally regarded to encompass four main products: geotextiles, geonets/geogrids, geomembranes and geocomposites. The synthetic nature of the products make them suitable for use in the ground where high levels of durability are required. Geosynthetics are available in a wide range of forms and materials, each to suit a slightly different end use. These products have a wide range of applications and are currently used in many civil and geotechnical engineering applications including roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, bank protection and coastal engineering.

24. **Geomicrobiology** is a subset of the scientific discipline microbiology. The field of geomicrobiology concerns the role of microbe and microbial processes in geological and geochemical processes

25. Glaciology:

26. **Historical geology** is the use of the principles of geology to reconstruct and understand the history of the Earth. It focuses on geologic processes that change the Earth's surface and subsurface; and the use of stratigraphy, structural geology and palaeontology to tell the sequence of these events. It also focuses on the evolution of plants and animals during different time periods in the geological timescale. The discovery of radioactivity and the development of a variety of radiometric dating techniques in the first half of the 20th century provided a means of deriving absolute versus relative ages of geologic history

27. Hydrogeology/Hydrology: the study of the origin, occurrence and movement of water in a subsurface system, primarily groundwater.

28. Igneous petrology: the study of igneous processes such as igneous differentiation, fractional crystallization, intrusive and volcanological phenomena .

29. Isotope geology: the study of the isotopic composition of rocks to determine the processes of rock and planetary formation.

30. Lithology:

31. Marine Geology:

32. **Medical geology** is an interdisciplinary scientific field consisting of those aspects of geology as they affect human, animal and plant health.

In its broadest sense, medical geology studies exposure to or deficiency of trace elements and minerals; inhalation of ambient and anthropogenic mineral dusts and volcanic emissions; transportation, modification and concentration of organic compounds; and exposure to radionuclide's, microbes and pathogens. (Geotimes 2001)

Examples include:

- Lead and other heavy metal exposure resulting from dust and other particulates
- Asbestos exposure such as Amphibole Asbestos dusts in Libby, Montana.
- Fungal infection resulting from airborne dust, such as Valley Fever or coccidioidomycosis.

33. Metamorphic petrology: the study of the effects of metamorphism on minerals and rocks such as composition and texture of metamorphic rocks (rocks such as slate, marble, gneiss, or schist which started out as sedimentary or igneous rocks but which have undergone chemical,

mineralogical or textural changes due to extremes of pressure, temperature or both).

34. Meteorology
35. Mineralogy:
36. **Nanogeoscience** is the study of geological processes involving particles no larger than 100 nanometers.
37. Oceanography:
38. Ore Geology:
39. Palaeoclimatology: the application of geological science to determine the climatic conditions present in the Earth's atmosphere within the Earth's history.
40. Palaeontology: the classification and taxonomy of fossils within the geological record and the construction of a palaeontological history of the Earth.
41. Palaeobotany:
42. **Palaeogeography** (sometimes spelled **paleogeography**) is the study of the ancient geologic environments of the Earth's surface as preserved in the stratigraphic record.
43. Palaeogeomorphology:
44. **Palynology** is the science that studies contemporary and fossil palynomorphs, including pollen, spores, dinoflagellate cysts, acritarchs, chitinozoans and scolecodonts, together with particulate organic matter (POM) and kerogen found in sedimentary rocks and sediments.
45. Pedology/Soil Science: the study of soil, soil formation, and regolith formation.
46. Petrology: Scientific study of rocks, such as its origin, nature of occurrence, structure and texture of rocks.

47. Petrography:

48. Petroleum geology: the study of sedimentary basins applied to the search for hydrocarbons (oil exploration).

49. **Planetary geology**, alternatively known as **astrogeology** or **exogeology**, is a planetary science discipline concerned with the geology of the celestial bodies such as the planets and their moons, asteroids, comets, and meteorites. Although the *geo* prefix typically indicates topics of or relating to the Earth, "planetary geology" is named as such for historical and convenience reasons. The study of rocks originated with studying rocks on Earth, and due to the types of investigations involved, planetary geology is closely linked with Earth-based geology.

50. Regional Geology:

51. Sedimentology: the study of sedimentary rocks, strata, formations, eustasy and the processes of modern day sedimentary and erosive systems.

52. Seismology:

53. Stratigraphy:

54. Structural geology: the study of fold (geology), geological fault, foliation (geology) and rock microstructure to determine the and deformational history of rocks and regions.

55. Volcanology: the study of volcanoes, their eruptions, lavas, magma processes and hazards.

SCOPE & IMPORTANCE OF GEOTECHONOLOGY

"There hasn't been a moment when I had the chance to look down on our planet from orbit when I haven't been amazed at how geology has played a significant role in the development of humankind."

- *Dr. James F. Reilly, Jr., NASA Astronaut/Geologist, reflecting on his experience working at the International Space Station.*

Not so long ago, we had the first view of our planet from space. We were startled to see how beautiful and how fragile our home appeared, "a pale blue dot" said Carl Sagan, very different from the other planets in our solar system. Our home — blue with water, white with clouds, green with life — is a planet unique in our solar system and probably rare in the universe.

Nearly everything we do each day is connected in some way to Earth: to its land, oceans, atmosphere, plants, and animals.

The food we eat, the water we drink, our homes and offices, the clothes we wear, the energy we use, and the air we breathe are all grown in, taken from, surround, or move through the planet Earth. **By 2025**, **eight billion people** will live on Earth. If we are to continue extracting resources to maintain a high quality of life, then we, as individuals and citizens, need to know more about our planet — its processes, its resources, and its environment.

Our lives and civilization depend upon how we understand and manage our planet — Earth processes affect us all. Weather patterns influence the availability of water resources and the potential for forest fires; earthquakes, volcanic eruptions, hurricanes, and floods can kill large numbers of people and cause millions or even billions of dollars in property damage. Just as Earth systems directly affect each of us, we — as individuals, communities and nations — affect our planet. Expanding technologies and growing populations increase demand on natural resources. As we extract and use these resources, we impact Earth today, which will in turn impact those who come after us. To enhance our stewardship of the environment, we must proceed into the future with a sound understanding of Earth systems.

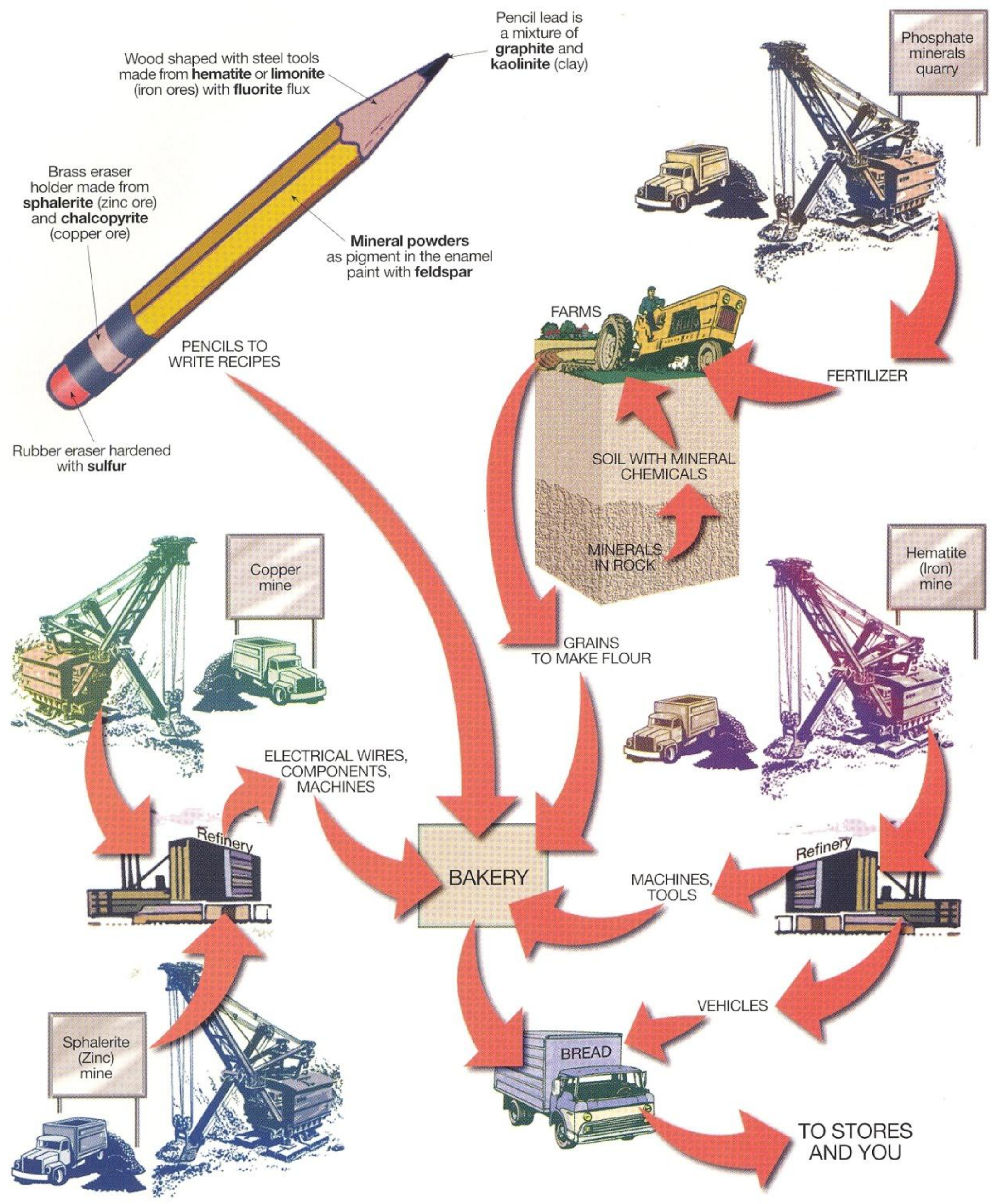


FIGURE 2.2 Flow diagram illustrating how minerals have been used to manufacture some common items that you probably use or eat everyday.

Earth science empowers us to think globally and act locally — to make sound decisions about issues important in our lives as individuals and citizens. People, who understand how Earth systems work, can make informed decisions about where to buy or build a home out of harm's way. They can debate and resolve issues surrounding clean water, urban planning and development, national security, global climate change, and the use and management of natural resources. An informed society, conscious of our complex relationships with our planet, recognizes the importance of and insists on Earth science. Thus Earth Science benefits everyone.

Earth Science Creates Informed Citizens

If we intend to live on — and with — this planet, we truly need to understand how it works, and to understand the interactions of the many components that make up the Earth. The Earth sciences provide an integrated and interdisciplinary approach to a true understanding of our planet. Earth science includes and applies knowledge from biology, chemistry, physics, ecology, and mathematics to tackle complex interdisciplinary issues. Earth science education also improves critical thinking skills. It offers a historical perspective and improves our ability to predict future events. To understand Earth processes that affect us now and tomorrow, geoscientists look for evidence of what happened in the past. This connects students to the past, as well as challenging them to think about the future.

Earth science poses questions that are exciting as well as practical to children and adults alike: Why is California prone to earthquakes? Why is the beach eroding and what can we do about it? Why isn't a floodplain a good location to build a house? Where will we get the fuel to power our cars and planes in the future? Where will we get fresh water to drink? How can I help to protect the environment? Earth science problems and issues are ideally suited for an inquiry based education approach — an educational process that most closely resembles the reality of scientific endeavor.

Earth science develops skills that help students become better problem solvers, including three-dimensional analysis and comprehension of time and scale. Earth scientists use these skills to ensure a supply of clean water, explore for oil, gas, and coal, map the oceans, track severe weather, and discover the Earth materials we need to build our homes and roads, and the minerals and nutrients we need to farm the land.

Earth scientists work for a wide range of organizations, including petroleum companies, environmental firms, mining companies, and construction companies. They work in local, state, and federal government agencies and teach in our schools, colleges, and universities. Earth scientists also work in non-traditional industries such as telecommunications and financial planning, assisting their organizations to address Earth-related issues that affect their activities. Training in the Earth sciences builds a foundation for work in other fields, and nearly half of those graduating with Earth science degrees establish careers in fields as varied as engineering, law, systems analysis, and financial management. Earth science provides a strong background for many career paths and instills an understanding of how the Earth system influences the many and varied aspects of human activity. However, many students graduate from high school unaware of the contributions that Earth scientists make to society and the unique problem solving skills that Earth science instills.

Earth Science Builds Careers for Life

Yet many people still think that biology, chemistry, and physics constitute a complete science education. In the 21st Century, that attitude is changing. The *National Science Education Standards* and the *Benchmarks for Science Literacy* define science literacy and reaffirm the centrality of Earth science in education. The *Standards* promote the idea that Earth science should be taught in parity with biology, chemistry, and physics as part of the country's national strategy for science literacy.

Earth science education enhances our understanding and appreciation of critical issues that affect every state, so it is imperative that students in every state graduate with a thorough understanding of Earth science. In every case, the education standards emphasize the importance of Earth science in producing well-rounded literate citizens.

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.

Basic knowledge about the Earth is the key to the development of an informed citizenry. The reasons for teaching Earth Science are numerous: it offers experience in a diverse range of interrelated scientific disciplines; it is closely related to the students' natural surroundings; and offers students subject matter which has direct application to their lives and the world around them. They need only step outdoors to observe and find relevance in concepts learned in the Earth Science classroom. Because it offers many opportunities to collect data, hypothesize, experiment, and draw conclusions, both within school and outside environments, Earth Science is a laboratory and activity oriented course. Earth Science integrates many principles of both physical and life sciences. It incorporates and presents concepts often not emphasized in other parts of the science curriculum, such as geologic time and the vastness of space.

Knowledge in Earth Science allows everyone to have a better science background with pertinent information about their surroundings. Daily, society is faced with environmental and economic concerns such as acid rain, water supply, the greenhouse effect, and waste disposal. Civilization is absolutely dependent upon utilization of Earth's energy, mineral, and human resource. Awareness of natural phenomena such as floods, tornadoes, hurricanes, volcanoes, and earthquakes also requires knowledge of Earth Science.

The students who study Earth Science are better prepared to discuss issues and make informed, responsible decisions. The interdisciplinary curriculum of Earth Science develops and builds on skills learned in earlier grades and closely relates to the students' everyday experiences. It develops attitudes and problem-solving skills that will be useful throughout life. If tomorrow's adults are to make wise decisions about Earth and environmental issues, it is vital that today's students be given the opportunity to study Earth Science at all levels as an integral part of their education as well as an invaluable part of their school / college education experience.

Hence, **Geotechnology** is important in,

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

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.

"PRESENT IS THE KEY TO THE PAST"

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

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:

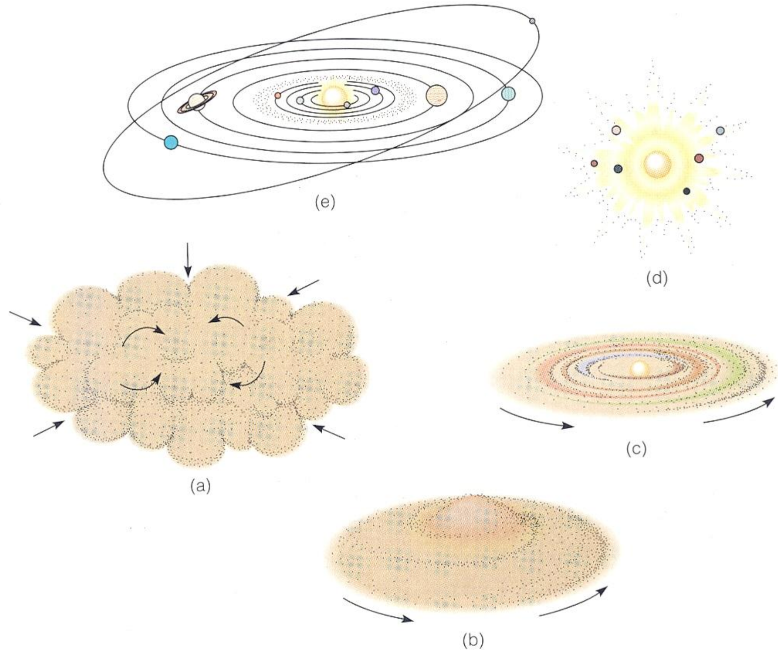
- Evolutionary Theories: These are based on later modification of pre-existing gas clouds. Forces responsible for it are all internal.
- Multistar Theories: Based on the collision or close by crossing of two or more stars. External force.
- Protosun Theories: Sun is supposed to form earlier and latter gathered the interstellar materials to form the disc.

In 1975, Kant proposed a hypothesis for the origin of Earth. Later it was modified to suit the other requirements of the solar system by Laplace. This theory has been called as Kant Laplace's Nebular hypothesis.

According to the Kant Laplace's Nebular hypothesis theory,

- 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 become 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.



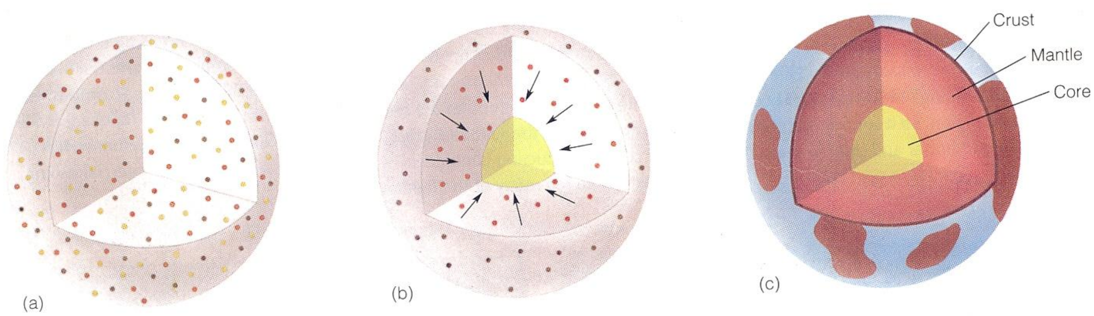


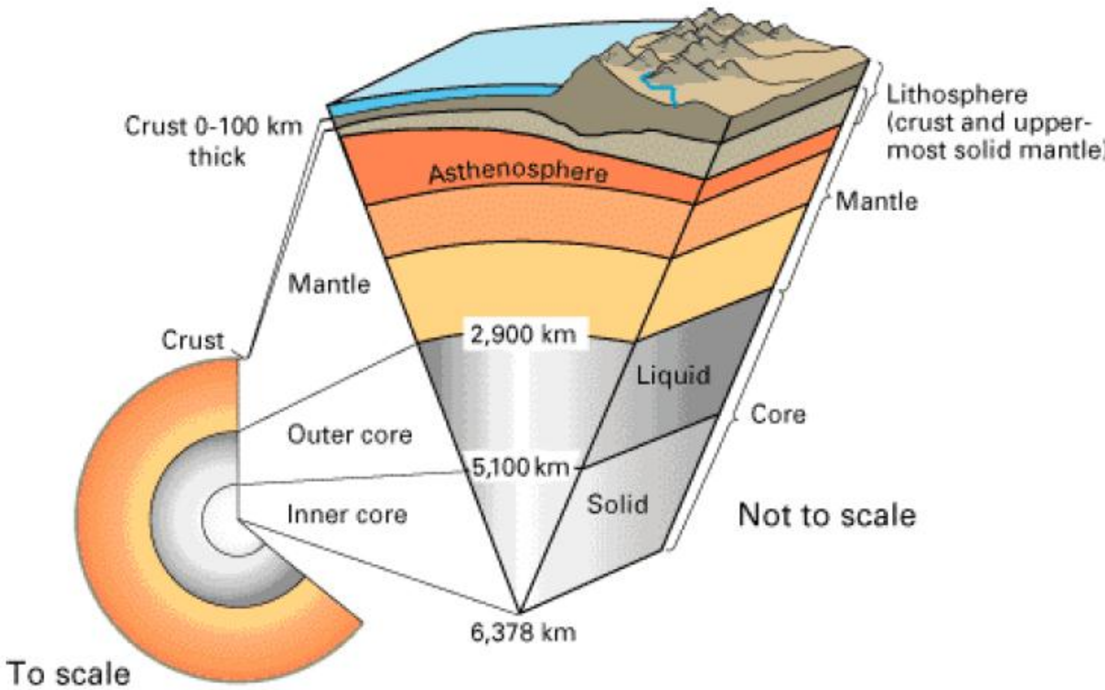
FIGURE 1.12 (a) Early Earth was probably of uniform composition and density throughout. (b) Heating of the early Earth reached the melting point of iron and nickel, which, being denser than silicate minerals, settled to Earth's center. At the same time, the lighter silicates flowed upward to form the 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

INTERIOR OF THE EARTH

No-one has ever penetrated Earth's mantle to reach the core to investigate what it is made of so much of what we "know" is theory based on intelligent deduction. Some deductions are based on good empirical (based on observation or experiment) data obtained by analyzing the seismic waves that are produced when earthquakes happen.

Seismic waves that travel through the deep interior of the Earth can sometimes be detected by seismographs in different parts of the world. Scientists observe where these waves reach the surface and how long it takes for them to get there. Comparing these observations with controlled experiments on the behavior of waves passing through different materials, scientists can then construct good theories about what materials deep in the Earth the seismic waves passed through on their way to the surface.



Composition of 3 Layers of the Earth

Continental Crust = SiAl = Silica & Aluminium
Oceanic Crust = SiMa = Silica & Magnesium

Mantle = FeMa = Iron & Magnesium = Semisolid or Plastic in nature

Core = NiFe = Nickel & Iron

- Inner core is Solid in narure- Though this has very high temperature, greater than the melting point (temperature) of the material, due to very high pressure, the inner core is in liquid condition.

- Outer core is in Liquid state.

AGE OF THE EARTH

There are several methods were tried to determine the age of the Earth: a) We can make educated guesses - in general, the deeper the rock, the older it is. Using this generalization geologists have created a relative time scale that describes what is older or younger but does not give a specific ages in years except in the most general terms; b) It is also possible by comparing the fossils in two different rock layers to tell that they are about the same age if the same types of fossils are found in each; c) radiometric dating such as the carbon-14 method can provide quite accurate specific ages of the remains of living things.

Based on the radiometric age dating of meteorite material and is consistent with the ages of the oldest-known terrestrial and lunar samples the age of the Earth is around 4.54 billion years. The modern geologists and geophysicists accept this age. Using the same method, the age of the Sun is derived as 4.57 billion years, it is about 30 million years older.

The quoted age of Earth is derived, in part, from the Canyon Diablo meteorite for several important reasons and is built upon a modern understanding of cosmo-chemistry, built up over decades of research.

Photographs 1 & 2. A fragment of the Canyon Diablo iron meteorite (left) taken from Barringer Crater, Arizona (right).

The Canyon Diablo meteorite was used because it is a very large representative of a particularly rare type of meteorite that contains sulfide minerals (particularly troilite, FeS), metallic nickel-iron alloys, plus silicate minerals.

The Canyon Diablo date has been backed up by hundreds of other dates, from both terrestrial samples and other meteorites. The meteorite samples, however, show a spread from 4.53 to 4.58 billion years ago. This is interpreted as the duration of formation of the solar nebula and its collapse into the solar disk to form the Sun and the planets. This 50 million year time span allows for accretion of the planets from the original solar dust and meteorites.

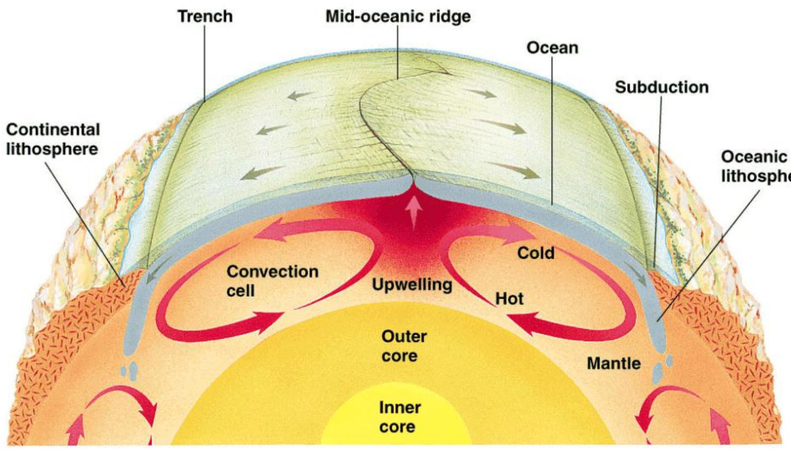
Most geological samples from Earth are unable to give a direct date of the formation of Earth from the solar nebula. Because the Earth has undergone differentiation into the core, mantle, and crust, and this has then undergone a long history of mixing and unmixing of these sample reservoirs by plate tectonics, weathering and hydrothermal circulation.

The moon, as another extraterrestrial body that has not undergone plate tectonics and that has no atmosphere, provides quite precise age dates from the samples returned from the Apollo missions. Rocks returned from the moon have been dated at a maximum of around 4.4 and 4.5 billion years old. Martian meteorites that have landed upon Earth have also been dated to around 4.5 billion years old by lead-lead dating. Lunar samples, since they have not been disturbed by weathering, plate tectonics or material moved by organisms, can also provide dating by direct electron microscope examination of cosmic ray tracks. Cosmic ray dating is only useful on material that has not been melted, since melting erases the crystalline structure of the material, and wipes away the tracks left by the particles.

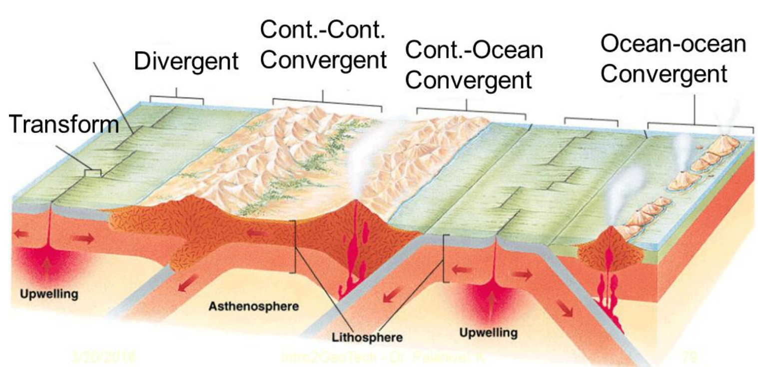
Altogether, the concordance of ages of both the earliest terrestrial lead reservoirs and all other reservoirs within the solar system found to date are supporting the hypothesis that the Earth and the rest of the solar system formed at around 4.53 to 4.58 billion years ago.

Plate Tectonics

- Lithosphere is broken into individual pieces called plates
- Plates move over the asthenosphere as a result of underlying *convection cells.*



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



4 types of Plate Boundaries are shown in the figure above.

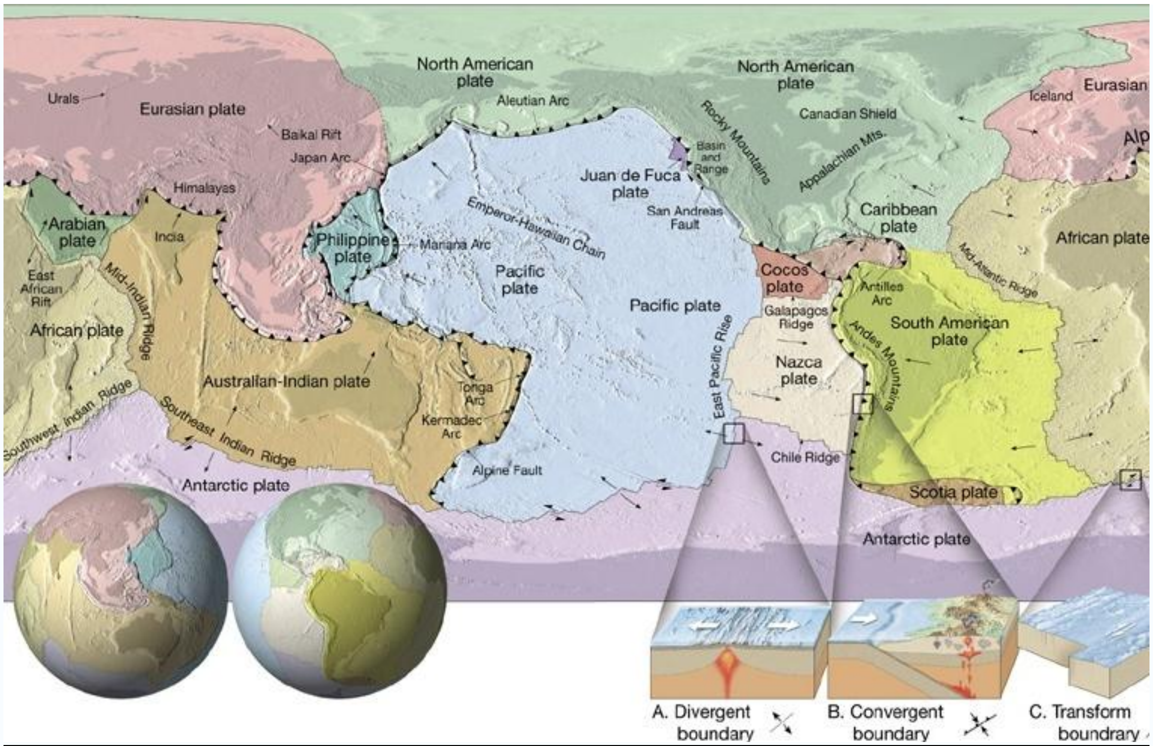
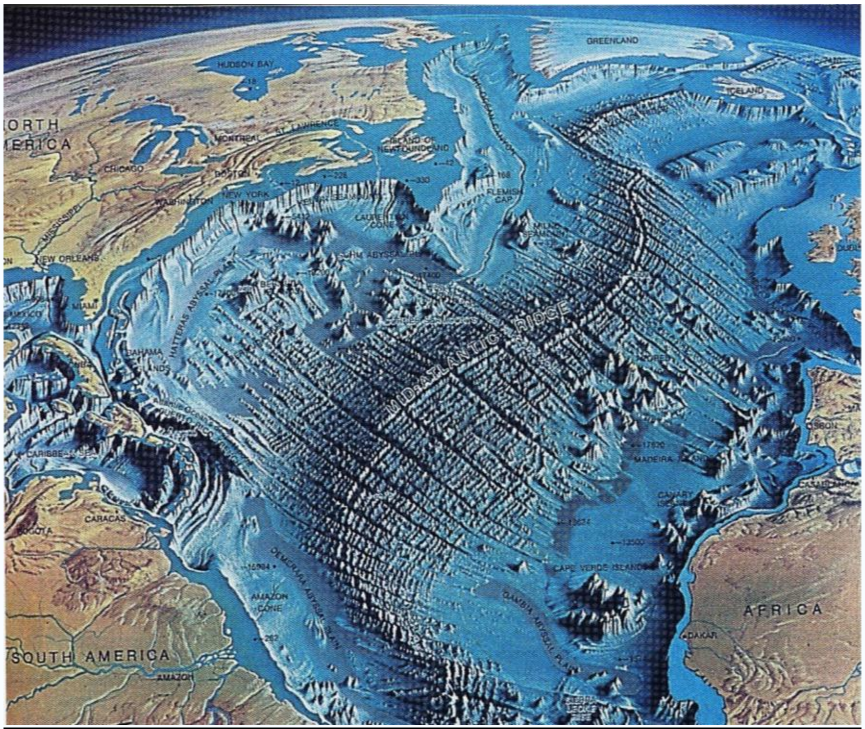


Table 2–1 • CHARACTERISTICS AND EXAMPLES OF PLATE BOUNDARIES

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



Mid ocean Ridge seen beneath the Ocean; These ridges are under Atalntic Ocean and hence the name Mid-Atlantic Ridge

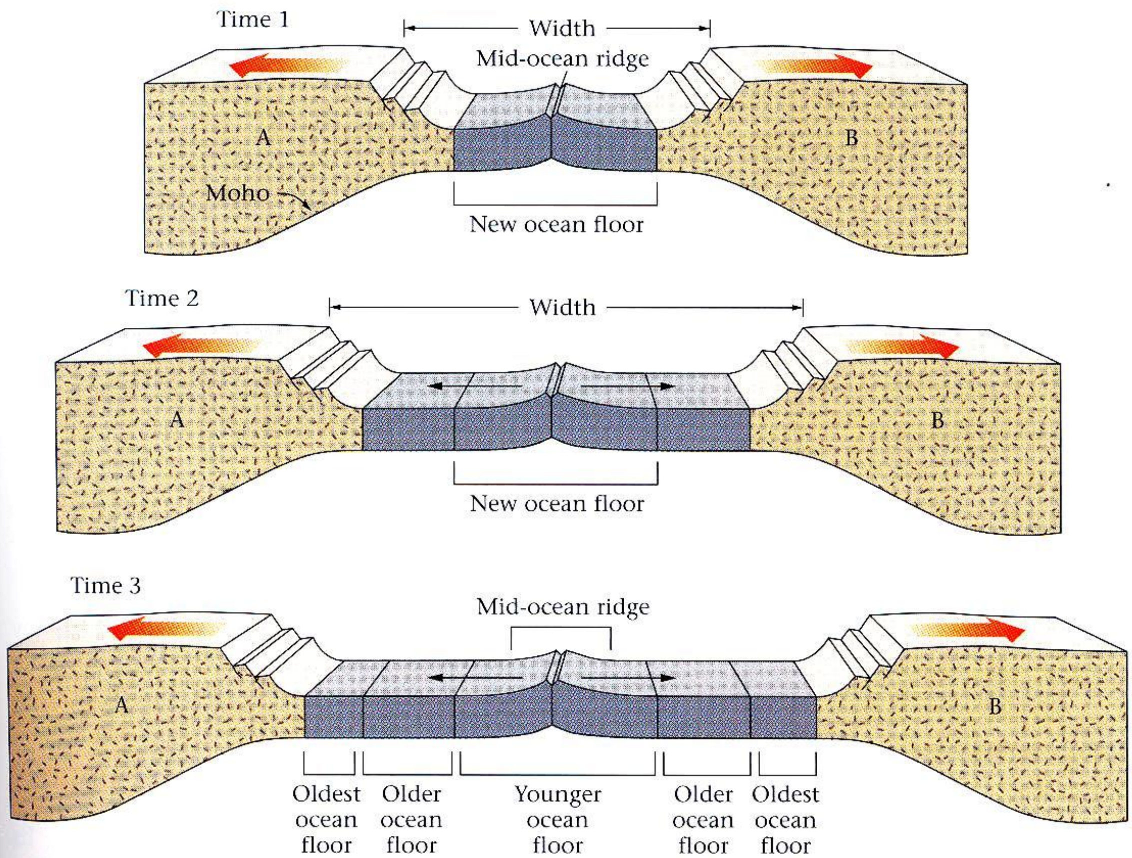


FIGURE 2.33 These sketches depict successive stages in sea-floor spreading along a divergent boundary (mid-ocean ridge); only the crust is shown. The top figure represents an early stage of the process, after the mid-ocean ridge formed but before the ocean grew very wide. With time, as seen in the next 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.

Formation of Continents & Oceans

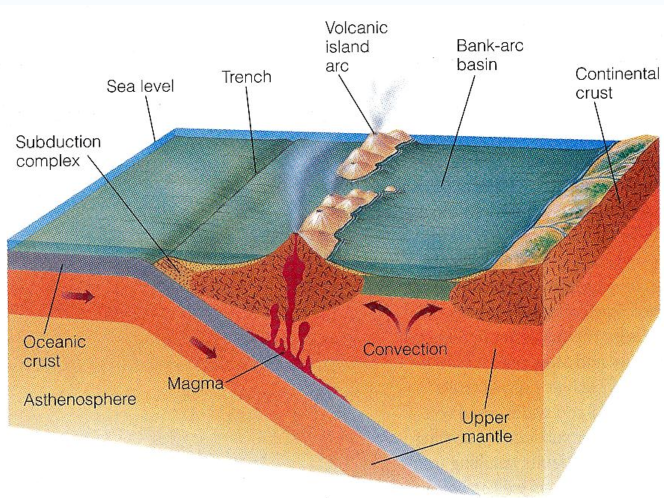


FIGURE 12.19 Oceanic–oceanic plate boundary. An oceanic trench forms where one oceanic plate is subducted beneath another. On the nonsubducted plate, a volcanic island arc forms from the rising magma generated from the subducting plate.

Mountain building activities

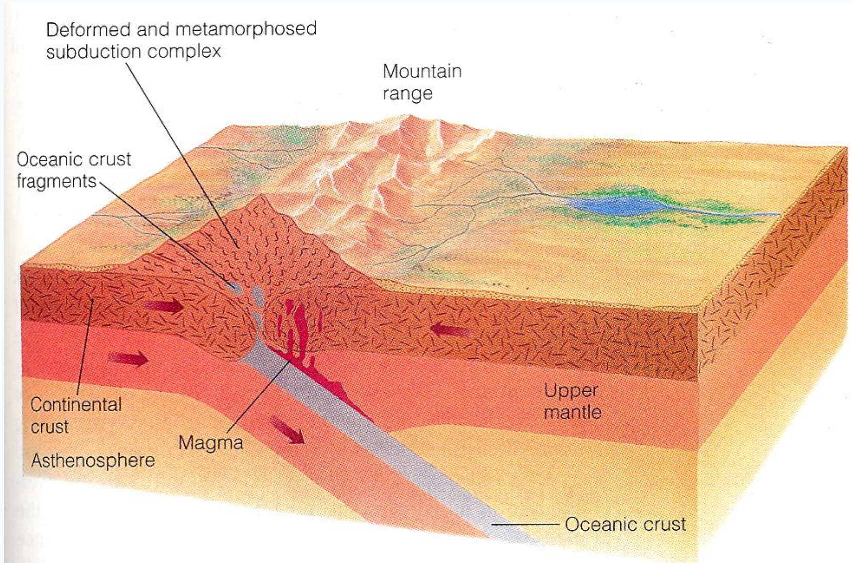


FIGURE 12.21 Continental–continental plate boundary. When two continental plates converge, neither is subducted because of their great thickness and low and equal densities. As the two continental plates collide, a mountain range is formed in the interior of a new and larger continent.

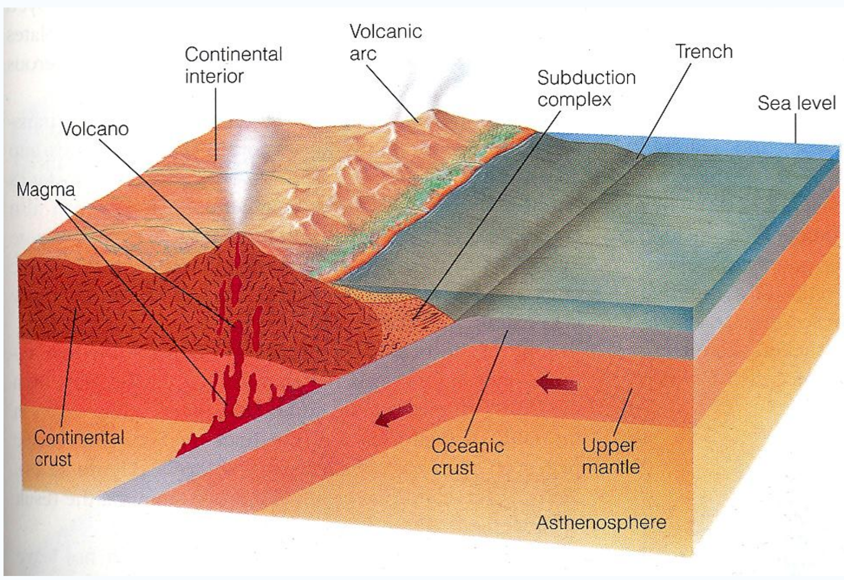


FIGURE 12.20 Oceanic–continental plate boundary. When an oceanic plate is subducted beneath a continental plate, an andesitic volcanic mountain range is formed on the continental plate as a result of rising magma.

- Mounds or inselbergs – i.e., Residual hills formed due to erosion of surrounding soil or weathered and soft material leaving the central hard rock / igneous plugs.
- Block mountains are formed due to tectonic upliftments or downslip movement of two adjacent blocks.

When Earth was first formed it was a solid ball of molten rock with no atmosphere. As Earth began to cool and the crust and mantle began to harden, material from the inner regions would sometimes erupt through the surface bringing hot gases. Scientists theorize (no-one really knows because no one was there!) that these gases were methane, ammonia, carbon dioxide and water (steam). The water eventually condensed to form oceans but almost certainly there was at first no oxygen or nitrogen in Earth's atmosphere.

It is believed that the atmosphere (air) that we now breathe was formed only after the development of the first living things, blue-green algae (now generally classified as blue-green bacteria), that happened about two billion years ago. These simple organisms used carbon dioxide during photosynthesis and gave off oxygen as a bi-product of the chemical process.

ORIGIN OF RIVERS

The initial source for water is from the cooled water vapour came out of volcanoes. The Condensation of vapour at a higher altitude above earth surface resulted in to rainfall or snow fall. When the ground (soil) is saturated with water, the water starts running down in tiny rivulets. Thus, source of every river is precipitation/rainfall, its spring, and/or melting water of a glacier. Springs are generally found in the higher grounds of a mountain range, which receive relatively receives large amounts of rainfall. In glacial regions, water usually collects in lakes and then flows down to the valley. Little channels and rivulets, first formed by the water, ultimately join into one water stream. This stream often uses troughs formed by glaciers or tectonic movements.

This is how a riverbed is formed. As the speed of the water increases, the water carves deeper into the rock and soil. The riverbed is literally carved out by sand and gravel washed out by water. This process is called abrasion. Valleys with more or less sloping walls form alongside the trough or channel. Even the hardest rocks in the vicinity of the riverbed may be eroded by the constant movement of washed out stones.

The channel of the stream may run straight, but may also be intricate. In general, a river in the valley floor moves in irregular direction. It often divides into various channels. A riverbed may be situated in the middle of a valley meadow or alongside its edge. In addition to straight river flow we have a meandering and braided river flows.

PHYSIOGRAPHY OF THE EARTH

The Earth's continental crust consists of three discernible units, each with their own characteristics. These units are cratons, mountain belts, and continental margins.

Cratons

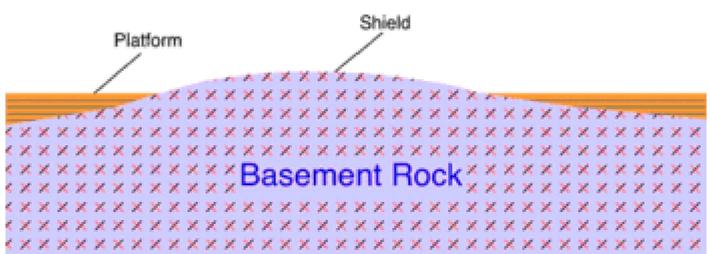


Figure: Cross section showing the relationship between basement rock and platform sedimentary deposits. Note that the surface of the basement rocks (the shield) is gently arched.

All of the continental masses on the Earth have a central foundation of very old basement rock. Basement rock is composed of mixtures of ancient granite, gneiss, schist, volcanic, plutonic, and sedimentary rocks. Some of the Earth's oldest rocks are found in this geologic formation. 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 2,000 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. The continents of Australia, North America, South America, and Africa each have a single continuous craton forming their nucleus. Eurasia is composed several distinct cratons that are separated from each other by the Alps, Ural, and Himalaya mountain belts.

The craton of North America has been relatively stable for about 600 million years. Prior to this period, the North American continent saw several periods of very active growth with the amalgamation of once distinct cratons and the addition of rock along its margins. Geologic evidence suggests that North America is made up of several once independent minicontinents. Scientists believe that the amalgamation of these minicontinents into the core of the North America continent was complete by about 2.5 billion years ago.

On a global scale, about 70 percent of the Earth's continental crust was formed by 2.5 billion years ago. Over the next 2 billion years, the planet's continents would continue to grow through the accretion of sedimentary rock and the addition of igneous rocks along the continental margins. This growth was also driven by tectonic processes. The accretion of sedimentary rock occurred with the collision of tectonic plates which pushed ocean sediments onto the continents. Plate subduction created enough heat to melt rock into magma beneath the margins of the continents. This magma then migrated upward through the crust to form intrusive and extrusive igneous features and deposits. This process also added significant mass to the continents.

Mountain Belts

Numerous mountain belts are also found on the continents. These features are often located on the edge of cratons. Mountain belts are the result of tectonic processes that cause to crustal plates to collide. This collision results in the folding and faulting of rock, igneous intrusive and extrusive activity, and metamorphism. The elevated relief common to mountain belts is generally caused by the compression of rock into a smaller area. Uplift may also be caused by the upward migration of magma through the crust to produce granitic batholiths. Some mountains occur in isolation like Mount Rainier in the state of Washington, USA. These features are volcanic and are produced by localized extrusive igneous activity.

Continental Margin

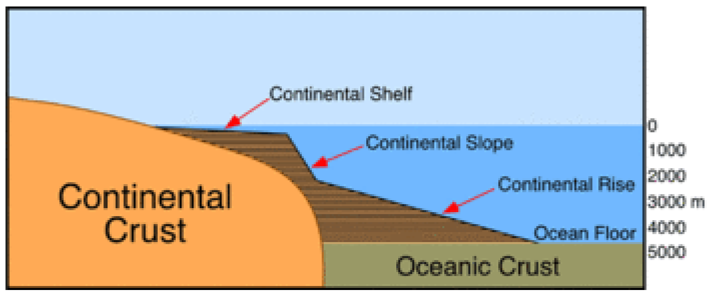


Figure: Marginal features found at the interface of the continents and the ocean basins.

Located between the terrestrial continents and the ocean basins is the continental margin. Two basic types of continental margin are recognized: active and passive. Active continental margins occur in the Pacific Ocean. Active margins are generally narrow tectonically active areas. They are also associated with earthquakes, oceanic trenches, and volcanoes. Passive continental margins are relatively wide and have a lack of volcanic activity and few earthquakes. The continental margin is actually made up of three structures: the continental shelf, the continental slope and the continental rise. Both the continental shelf and slope are structurally part of the continents, even though they are below the sea surface.

The continental shelf is a shallow (average depth 130 meters), gently sloping part of the continental crust that borders the continents (Figure 2). The extent of this feature varies from tens of meters to a maximum width of about 1,300 kilometers.

The continental slope extends from the continental shelf at an average depth of about 135 meters. The base of this steeply sloping (from 1 to 25°, average about 4°)

topographic feature occurs at a depth of approximately 2,000 meters, marking the edge of the continents. The width of the slope varies from 20 to 100 kilometers. The boundary between the continental slope and shelf is called the continental shelf break.

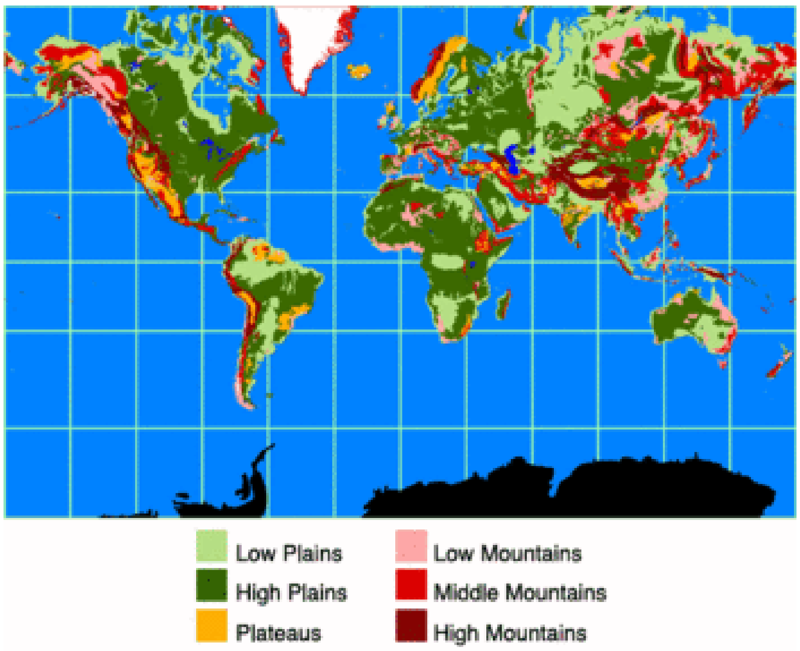


Figure : The Earth's various topographic regions. The legend below describes the colors associated with the six topographic regions shown. Glaciers are colored white.

At the base of the continental slope an accumulation of sediments may develop. This accumulation of sediments is properly known as the continental rise. The continental rise is composed of number abyssal fans that run side-by-side along the edge of the continental slope. Abyssal fans are usually associated with a deep submarine canyon cut into the continental slope. Underwater abyssal fans can be compared to terrestrial landforms known as alluvial fans. The sediments that make up this feature are transported down the continental slope by turbidity currents, underwater landslides, and several different processes that move clay, silt, and sand. Most of this sediment is terrestrial in origin. The depth of the continental rise ranges from 2,000 to 5,000 meters deep. The continental rise can be as much as 300 kilometers wide.

Topography of the Terrestrial Surface

The above Figure classifies the Earth's terrestrial surface in to six different categories based on topography. Most of the Earth's terrestrial surface is dominated by reltively flat low and high plains. The low plains tend to be areas of sediment deposition because of their low elevation. The high plains can have elevations as high as 600 meters and are more strongly influenced by erosion. Both of these topographic features are often associated with cratons and their exposed shield and platform surfaces. Local relief on both types of plains is less than 100 meters. The three types of mountains shown in Figure 3 have local relief in excess of 500 meters and slope angles greater than 5°. Many of the "low" mountains are very old structures that have been reduced in height by erosion. Plateaus have altitudes that are greater than the high plains but less than mountains. Local relief of this topographic feature varies between 100 and 500 meters. Some plateaus are the remnants of eroded mountains. Others have formed because of large-scale block-faulting.

Unit-2 LITHOLOGY

Study of rock types and their physical and chemical characters is known as lithology.

Rocks are composed of one or several rock forming minerals – mostly of Silicates of Aluminium, Sodium, Calcium, Potassium, etc.

Other rock forming minerals are: Oxides, Sulphides, Carbonates, etc.

Minerals:

Mineral is a naturally occurring inorganic solid substance that is charact-erized with a definite chemical composition and very often with a definite atomic structure.

In nature more than two thousand minerals are known to occur.

These minerals generally occur in group and form a rock.

Rock forming minerals :

The common minerals that constitute the main composition of the rock are called rock forming minerals.

Though there are thousands of minerals only few minerals form the great bulk of the rocks of the crust of the earth.

Even among this only 25% or so make up almost 99.5% of common rocks.

There are three groups which covers most of the common rock forming minerals. They are: Silicates, Oxides & Carbonates.

Rock-Forming Minerals

MINERAL	COMPOSITION	PRIMARY OCCURRENCE
Ferromagnesian silicates		
Olivine	$(Mg,Fe)_2SiO_4$	Igneous, metamorphic rocks
Pyroxene group		
Augite most common	Ca, Mg, Fe, Al silicate	Igneous, metamorphic rocks
Amphibole group		
Hornblende most common	Hydrous* Na, Ca, Mg, Fe, Al silicate	Igneous, metamorphic rocks
Biotite	Hydrous K, Mg, Fe silicate	All rock types
Nonferromagnesian silicates		
Quartz	SiO_2	All rock types
Potassium feldspar group		
Orthoclase, microcline	$KAlSi_3O_8$	All rock types
Plagioclase feldspar group	Varies from $CaAl_2Si_2O_8$ to $NaAlSi_3O_3$	All rock types
Muscovite	Hydrous K, Al silicate	All rock types
Clay mineral group	Varies	Soils and sedimentary rocks
Carbonates		
Calcite	$CaCO_3$	Sedimentary rocks
Dolomite	$CaMg(CO_3)_2$	Sedimentary rocks
Sulfates		
Anhydrite	$CaSO_4$	Sedimentary rocks
Gypsum	$CaSO_4 \cdot 2H_2O$	Sedimentary rocks
Halides		
Halite	NaCl	Sedimentary rocks

*Contains elements of water in some kind of union.

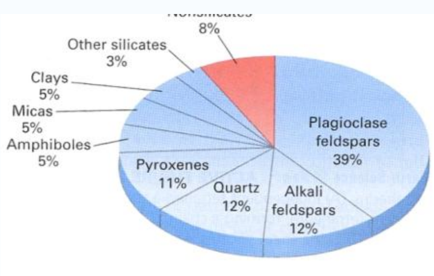


Figure 2.16 The silicate minerals compose 92 percent of the Earth's crust. Feldspar alone makes up about 50 percent of the crust, and pyroxene and quartz constitute another 23 percent. *Source:* Modified from Klein, *Manual of Mineral Science*, 22nd ed., John Wiley & Sons, Inc, 2002

Table 2–5 Common rock-forming silicate minerals

Silicate mineral	Composition	Physical properties
Quartz	Silicon dioxide (silica, SiO_2)	Hardness of 7 (on scale of 1 to 10); will not cleave (fractures unevenly); specific gravity: 2.65
Potassium feldspar group	Aluminosilicates of potassium	Hardness of 6.0–6.5; cleaves well in two directions; pink or white; specific gravity: 2.5–2.6
Plagioclase feldspar group	Aluminosilicates of sodium and calcium	Hardness of 6.0–6.5; cleaves well in two directions; white or gray; may show striations on cleavage planes; specific gravity: 2.6–2.7
Muscovite mica	Aluminosilicates of potassium with water	Hardness of 2–3; cleaves perfectly in one direction, yielding flexible thin plates; colorless; transparent in thin sheets; specific gravity: 2.8–3.0
Biotite mica	Aluminosilicates of magnesium, iron, potassium, with water	Hardness of 2.5–3.0; cleaves perfectly in one direction, yielding flexible thin plates; black to dark brown; specific gravity: 2.7–3.2
Pyroxene group	Silicates of aluminum, calcium, magnesium, and iron	Hardness of 5–6; cleaves in two directions at 90°; black to dark green; specific gravity: 3.1–3.5
Amphibole group	Silicates of aluminum, calcium, magnesium, and iron	Hardness of 5–6; cleaves in two directions at 56° and 124°; black to dark green; specific gravity: 3.0 3.3
Olivine	Silicate of magnesium and iron	Hardness of 6.5–7.0; light green; transparent to translucent; specific gravity: 3.2–3.6
Garnet group	Aluminosilicates of iron, calcium, magnesium, and manganese	Hardness of 6.5–7.5; uneven fracture, red, brown, or yellow; specific gravity: 3.5–4.3

Rock Types:

1. Igneous rocks, 2. Sedimentary Rocks & 3. Metamorphic rocks.

1. *IGNEOUS ROCKS*

Definition: These are the rocks formed by the solidification of Magma either underneath the surface or above it.

All the rocks have been formed initially and also originally from a hot molten material (Magma) through the process of cooling and crystallization.

The three major types of igneous rocks are: Plutonic, Hypabyssal & Volcanic rocks.

Plutonic rocks:

- Formed at considerable depths – generally 7 – 10 kms below the surface
- Very slow rate of cooling, hence there is sufficient time for crystallization
- So the igneous rock contains coarse grained crystals in it.
- Exposed at the surface due to erosion of the overlying strata.

Hypabyssal rocks:

- Formed at intermediate depth (up to 2 km below)
- Rate of cooling is faster than plutonic rock due to low temperature of surrounding rock
- So intermediate grain size, porphyries are common.

Volcanic rocks:

- Formed at surface of the earth
- Very fast cooling rate because of atmosphere and water contact (sudden chilling)
- So very fine grained or even glassy.

2. SEDIMENTARY ROCKS

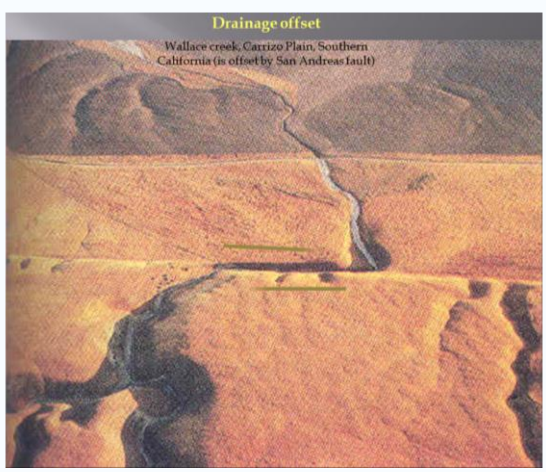
- This sort of rock is formed from sediments that have accumulated and over long periods of time have consolidated into rock.
- The sediments are often fragments that have been worn away from pre-existing rocks by a mechanical process such as the abrading action of wind, water or ice.
- Examples of sedimentary rock formed from such fragments are Conglomerates, Sandstones, and Shales.
- Sedimentary rocks are also formed from sediments (precipitates) that are the result of chemical action.
- Examples are Evaporites and sedimentary iron ores.
- Organic sedimentary rocks are formed from the remains of plants and animals. Examples are Coal and Limestones.

3. METAMORPHIC ROCKS

- This type of rock is rock that has been changed from its original form by high temperatures, pressures, or chemical action in such a way that its structure is changed.
- For example, a fine-grained Limestone, subjected to increased pressure and temperature, can change over time into Marble.
- Two other metamorphic rocks are Slate and Quartzite. Slate is a dark, smooth rock that breaks into smooth flat sheets of rock - it was once Shale; Quartzite is usually yellowish brown and one of the toughest rocks - was once Sandstone.
- Marble can be many colors depending upon the types of minerals that were in the particular sedimentary limestone from which it was made.
- Marble is often a beautiful rock and has been a favorite material for sculptors and builders over the ages.

STRUCTURE

- Scientific study of geological structures, their formation, importance is known as Structural Geology.
- Folds, faults, Geotectonics and their significance
- Folds and Faults are very important for the occurrence of variety of natural resources
- At the same time they help us in identifying and delineating disaster hazard zones
- Tectonic history of terrain can be easily understood by studying these structures and the formation.
- There are variety of structural landforms are derived on the surface of the Earth. They are: Anticline, Syncline, Dome, Basin, Doubly Plunging Anticline, Doubly Plunging Syncline. Apart from them linear structural features such as Lineament, Fault, Fracture, Shear, Unconformity are also present.



GEOMORPHOLOGY

Scientific study of landforms developed on the Earth surface due to different systematic process of Earth is known as Geomorphology.

SUBDISCIPLINES OF GEOMORPHOLOGY - Based on the dominating geological processes for their formation

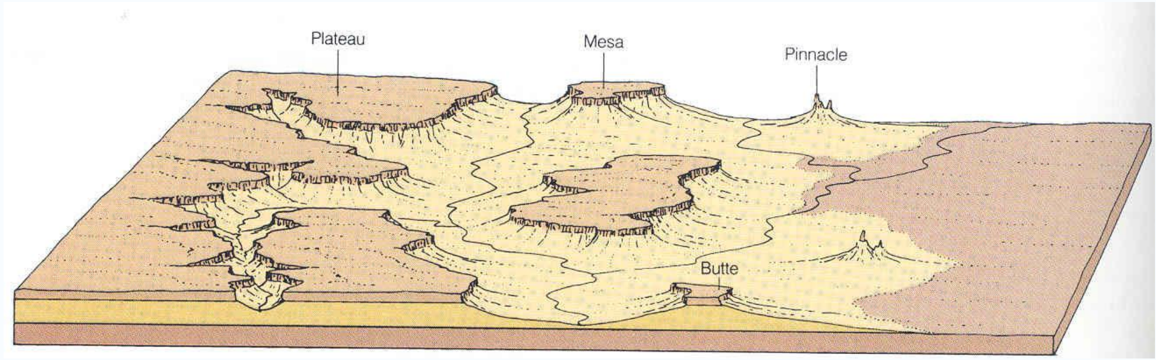
- ✓ Structural Geomorphology
- ✓ Denudational Geomorphology
- ✓ Glacial Geomorphology
- ✓ Fluvial Geomorphology
- ✓ Aeolian Geomorphology
- ✓ Coastal Geomorphology
- ✓ Fluvio-Marine Geomorphology, etc.

Regional geomorphic landforms in India

- Structural hills and denudational hills of Himalayas, Aravalli, Satpura mountains, Eastern and Western Ghats
- Plateau (plateaux) of Deccan trap rocks – Maharashtra
- Central plains covering the states central India.

GEOMORPHOLOGY UNITS (based on NRSC guidelines)
(for satellite image interpretation)

HILLS & PLATEAUS



Hills
Structural hills
Denudational hills
Residual hills

Other landforms

Plateau
Valley
Linear-curvilinear ridge
Valley fill shallow/moderate/deep
Cuesta
Dyke ridge
Mesa
Escarpment slope
Butte
Valley flat
Inselberg
Residual mound
Fracture / fault line valley
Sheet rock
Intermontane valley

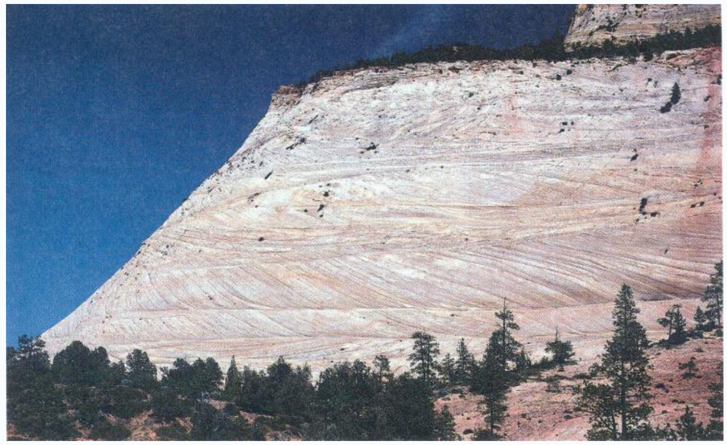
PIEDMONT ZONE

Piedmont slope, Pediment, Pediment-inselberg complex, Piedmont alluvium, Bazada, Gullied land, Ravenous land, Talus cone.

PLAINS

Pediplain
Weathered Pediplain
Buried Pediplain
Lateritic plain
Stripped plain
Alluvial plain

Fluvial Geomorphic features



Channel bar,
Flood plain,
Point bar,
Natural levee, Back swamp,
Cut-off meander,
Ox-bow / serpentine lake,
Meander scar,
Palaeo channel,
Buried channel,
Migrated river course,
River terrace.
Deltaic plain.

Flood plain – A Fluvial Geomorphic unit formed by River derived sediments deposited over various Geological periods under variety of climates. The above photograph shows a part of river dumped sediments showing layering, flow pattern, direction of flow, environment of deposition, etc., and now emerged as a hill after deep burial, compaction, cementation and induration.

Aeolian Geomorphic landforms

Sand dune, Stabilized dune, Dune complex, Interdunal depression, Interdunal flat, Playa, Desert pavement, Loess plain.

Coastal Geomorphic landforms

Beach, Beach ridge, Palaeo beach ridge, Beach ridge & swale complex, Palaeo beach ridge & swale, Older mud flat, Tidal flat, Salt flat, Lagoon , Channel island, Offshore island, Reef island, Spit, etc.

Glacial Geomorphic landforms

Glacier, U-valleys, Hanging valleys, Cirque, Arete, Avalanche, Moraines, Drumlins, Snout.

UNIT-3 NATURAL RESOURCES & NATURAL DISASTERS

NATURAL RESOURCES

- Naturally occurring materials which are playing major role as essential for human life.

They are:

- ❖ Mineral Resources
- ❖ Petroleum & Gas - Hydrocarbon
- ❖ Water Resources
- ❖ Soil Resources
- ❖ Forest Resources
- ❖ Biomass – Plants & Animals
- ❖ Ocean Resources.

How these Natural Resources were utilised by our forefathers?

How did our ancestors safeguarded they themselves as well as Natural Resources from Natural Disasters/ Calamities?

It is high time to recall / understand the methods adopted by our Ancestors in preventing destructions through ND and utilize the NR sustainably.

Mineral Provinces of India and exploration strategies

- BIHAR – Coal - Bituminus, Copper @ Mosabani, Uranium @ Jaduguda,
- RAJASTHAN - Marble
- ORISSA, Kerala – Radioactive Placer Minerals – Illmenite
- MAHARASHTRA – Slate, Irone Ore @ Kudremukh
- MADHYAPRADESH – Diamond
- ANHDHRAPRADESH – Barite, Asbestos, Mica, Quartz, Feldspar,
- KARNATAKA – Gold @ Kolar.

Mineral Provinces of Tamil Nadu

- Tiruchirappalli - Granite
- Ariyalur – Limestone – fossiliferous, Phosphatic nodules, Gypsum
- Cuddalore – Sandstone
- Neyveli – Lignite, White clay, Red clay
- Sivanganga – Graphite
- Madurai - Melur – Granite varieties
- Salem – BMQ Banded Magnetite Quartzite, Magnesite,
- Yercaud – Bauxite (exploited)
- Melur – Granite,

EXPLORATION STRATEGIES

- Preliminary survey – using remote sensing data
- Map favourable areas through different anomalies derived using remote sensing data
- Do local survey – Geophysical and Geochemical surveys
- Locate the exact targets
- Drill bore hole and do sampling & analysis
- Estimate the Quality and Quantum of resources and plan for exploitation.

Problems in Mining - Area & Resource Specific

- Lignite – Being Mined by NLC – During exploration phase, they were able to determine, some natural problems that could cause serious disaster in series such as,
    - the huge amount of pressure of the subsurface Artesian Aquifer – entire mine may get exploded at any stage
    - The mixture of phosphorous and sulfides which pose fire problems during summer

    - The access benches, made of Loose unconsolidated sediments may pose problem like soil erosion, soil slip, landslides.

HYDROCARBON PROVINCES

- In india, gulf of cambay, offshore mumbai
- Dispur, angaleshwar @ assam
- Cauvery delta-bhuvanagiri
- Krishna-godavari delta
- Moreover, possible occurrences at ganga basin, cudappah basin, deccan synclise, etc., are under study – possibilities are proved.

WATER RESOURCES

- Surface water – tanks, reservoirs, lakes, rivers and canals
- Groundwater – sedimentary aquifers, hard rock aquifers – crystalline aquifers
- All the Indian river basins are yielding good amount of groundwater
- Exploration strategies
    - Remote sensing survey
    - Ground truth surveys – Geological – wherever necessary
    - GIS integration
    - Identify GW targets and suggest suitable Artificial Recharge Schemes to improve the aquifers and their health.

SURFACE WATER & GROUND WATER PROVINCES IN INDIA

- Ganges, brahmaputra, narmada, tapti, krishna, godavari, cauvery, vaigai, tambraparni are some of the major river basins in india
- Several major reservoirs, colonies / swarms of tanks are also available
- Hot water springs in deccan, himalayas, etc., are also attracting attention
- Major river basins are also having their own alluvial aquifers – very good for ground water provinces

- Sedimentary-glacial, gondwana – coastal aquifers and hardrock aquifers are good provinces for ground water.

Natural resources in India – Some facts

- India's total renewable water resources are estimated at 1,907.8 km3/year.
- Its annual supply of usable and replenishable groundwater amounts to 350 billion cubic meters.
- Only 35% of groundwater resources are being utilized.
- About 44 million tonns of cargo is moved annually through the country's major rivers and waterways.
- Groundwater supplies 40% of water in India's irrigation canals.
- 56% of the land is arable and used for agriculture.
- Black soils are moisture-retentive and are preferred for dry farming and growing cotton, linseed, etc.
- Forest soils are used for tea and coffee plantations. Red soil have a wide diffusion of iron content.
- Most of India's estimated 5.4 billion barrels (860,000,000 m3) in oil reserves are located in the Mumbai High, upper Assam, Cambay, the Krishna-Godavari and Cauvery basins.
- India possesses about seventeen trillion cubic feet of natural gas in Andhra Pradesh, Gujarat and Orissa.
- Uranium is mined in Andhra Pradesh, Bihar-Jduguda.
- India has 400 medium-to-high enthalpy thermal springs for producing geothermal energy in seven "provinces" — the Himalayas, Sohana, Cambay, the Narmada-Tapti delta, the Godavari delta and the Andaman and Nicobar Islands (specifically the volcanic Barren Island.)
- India is the world's biggest producer of mica blocks and mica splittings.
- India ranks second amongst the world's largest producers of barites and chromites.

- The Pleistocene system is rich in minerals. India is the third-largest coal producer in the world and ranks fourth in the production of iron ore.
- It is the fifth-largest producer of bauxite and crude steel, the seventh-largest of manganese ore and the eighth-largest of aluminium.
- India has significant sources of titanium ore, diamonds and limestone. India possesses 24% of the world's known and economically-viable thorium, which is mined along shores of Kerala.
- Gold had been mined in the now-defunct
- Kolar Gold Fields in Karnataka.

EXPLORATION STRATEGIES

- Preliminary survey – using remote sensing data
- Map favourable areas using different anomalies derived using remote sensing
- Do local survey – geophysical and geochemical surveys
- Locate the exact targets
- Drill bore hole and do sampling & analysis
- Estimate the resource and plan for exploitation.

The mineral resources are extracted in several different ways. For example, when tiny grains of gold are spread through a gravel deposit the gravel is poured onto a table that is coated with mercury. When the table is vibrated the gold grains work their way to the table surface and combine with the mercury. This method works because gold has a strong tendency to combine with mercury. The gold, of course, then has to be separated from the mercury. A different method is used to separate sulphide (sulfide) minerals from others in order to obtain their sulphur. In this case the conglomeration of minerals might be finely ground up and then vigorously mixed in a tank of water through which air is being bubbled. In this process, which is called flotation, the sulphide minerals cling to the bubbles and are collected from the froth that spills over the top of the tank.

GEOHAZARDS & NATURAL DISASTERS

- ⦿ Geohazards are Geological phenomenon / processes vulnerable to the human's and other living being's life, their property as well as environment.
- ➢ Natural disasters are extreme events within the earth's system
- ➢ that results in massive destruction, i.e., death or injury to humans, and damage or loss of valuable goods…,
- ➢ …such as buildings, communication systems, agricultural land, forest, natural environment etc.

GEODYNAMIC PROCESSESS & NATURAL DISASTERS - GEOLOGICAL & CLIMATE RELATED

- Volcanoes – hill, plain & ocean
- Landslides – hill & submarine
- Soil erosion – hill, foot hill & undulating plains
- Flood – down stream slopes & plains
- Tsunami - coast
- Land subsidence - plains
- Earth quake – hill, plain, & ocean
- Cyclone – coast & adjacent plains.
- Drought – desertic plains, ice deserts.

CLASSIFICATION OF NATURAL DISASTERS

Based on the time taken to happen in an area:

- **Rapid Occurring Disasters** – Causes Immediate destruction, e.g. Earthquakes, Landslides…
- **Slow Occurring Disasters** – sluggish type over a period of several months and years – e.g. Soil Erosion, Drought…

NATURAL DISASTERS – CAN ALSO BE CLASSIFIED INTO 3 TYPES BASED ON

- Natural processes induced – eg. Earthquake and volcanoes by plate tectonism
- Human activites induced – eg. Reservoir induced earthquake by Koyna dam in maharastra state
- Induced by the intervention of both human activities and natural processes – landslides of thirumala hills

What can be done?

- Remote sensing / geotechnology based vulnerable area identification
- Damage estimation after the event
- Forecasting for evacuation & preparedness
- Inducing parameters identification
- Suggestion of remedial measures, mitigation and management plans.

Disaster Chains

- **Earthquake** (May 12) induced **landslides** have blocked the Tangjiashan river formed a very big **Quake Lake**.
- Water level raised to 738.71m and **inundated** the forest area
- More than 2,50,000 have to be relocated
- More than 600 armed police and soldiers dug a 475m-channel to divert the water
- More than 30 such unstable lakes formed.

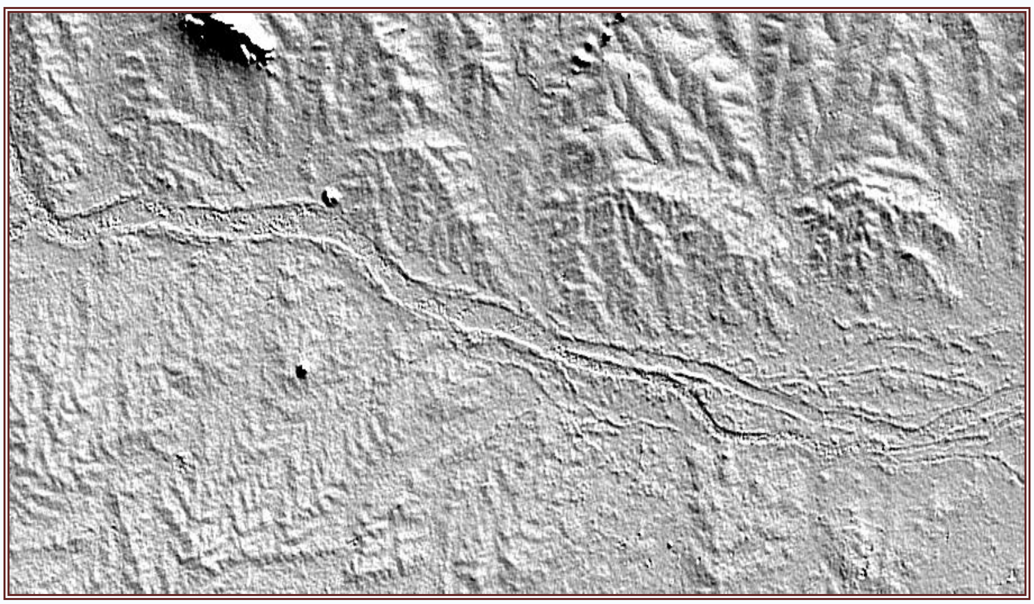
If these precautionary measures could not have been done, then the Quake lake will burst out and **flood** the downstream area and further while this gets mixed with soft sediments then that will form a slurry and can move faster along the downstream slopes, named **'Lahar'**, which can bury the villages or destroy the habitations. Thus, the natural disasters can happen as a chain, initiated through a major disaster and then by inducing one after the other.

FLOOD

Flood disaster can be forecasted, mapped, monitored and remedial measures to mitigate it. Further, the flood water can also be harvested during monsoon period so as to minimize flood destruction. The Geomatics technology plays a very major role in dealing with flood disaster.

MAPPING OF FLOOD VULNERABLE AREAS

(E.g. Tiruchirappalli area) using SHADED RELIEF MAP

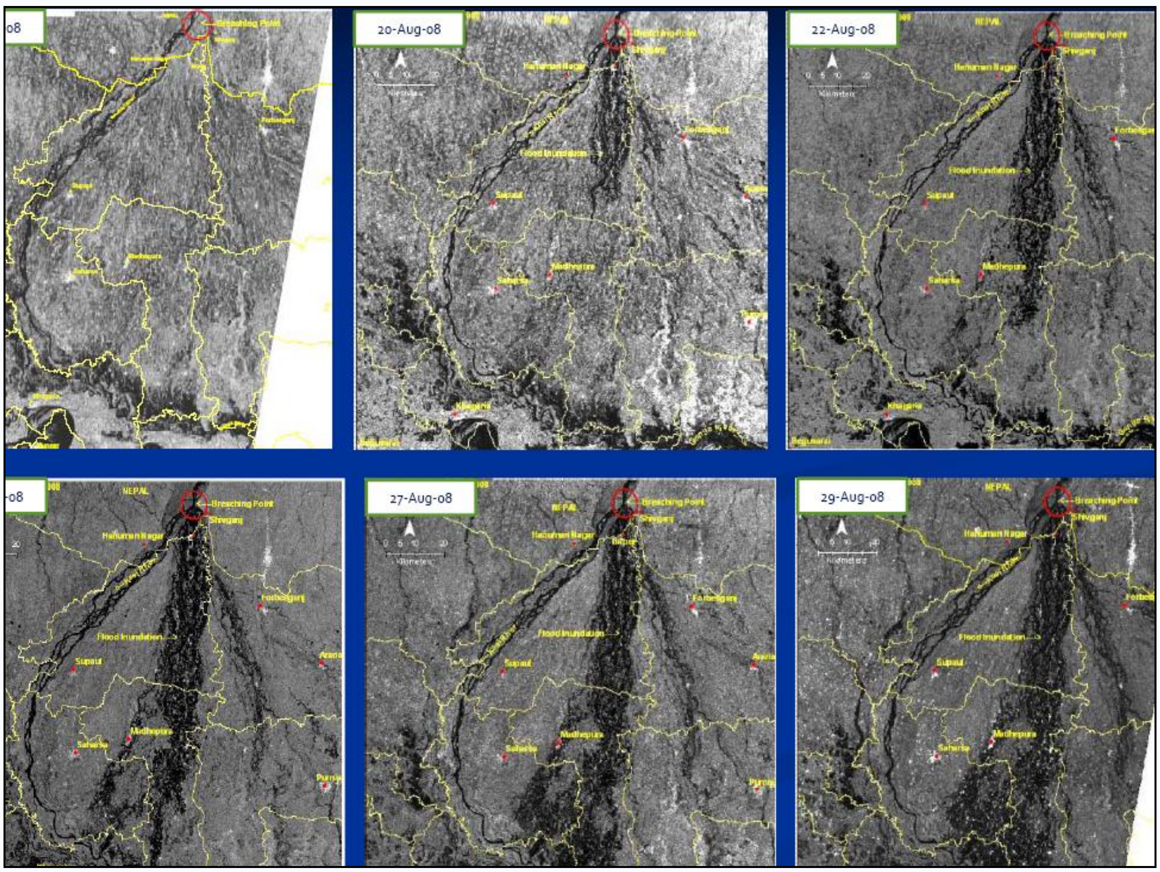


Using - SRM (flat and low lying areas), - Quantum of water flow, - Soil properties, soil conditions (Dry-Damp-Wet)

TSUNAMI

- Reasons for Tsunami
    - Submarine Earthquake based plate disposition
    - Landslides and massive rockfalls along rocky seacliffs
    - Massive snow avalanches along sea sides
    - Submarine volcanic explosion, etc.

- On time prediction – will help us to forewarn the people along sea shore as the waves take time to reach the shore.
- Natural Geomorphic landforms developed along the coast need to be protected and maintained as such – to minimise the destruction due to tsunami.
- Promoting Mangrove plantation – will mitigate tsunami



The above satellite images are Temporal data of RadarSAT showing Lake Breaching at Shivganj and the flood water inundated Midhepura and other downstream areas in Nepal.

Aerial & Satellite Remote Sensing - Principles

Remote Sensing – An art, science and technology of identification of Earth surface features or objects from atmosphere or space, without having any physical contact with the Earth surface.

Aerial Remote Sensing

Acquire aerial photographs with 60% overlap with every adjacent topographs in a particular flight path and with 30% sidelap with every successive flight path so as to get 3D stereoscopic view of the terrain whenever viewed with stereoscopes or similar electronic /digital equipments in laboratory.

Satellite Remote sensing

Acquire images from satellites in a particular orbit which are having sensors devised for capturing multiple Electromagnetic spectrums which are reflected / refracted Sun light, or targeted energy source of satellites that are reflected / refracted or self-energy of Earth emitted towards satellites in space, everything from Earth surface objects, and enable periodic or continuous monitoring due to their repeatability of acquiring data, by orbiting in the same orbital plane encircling the Earth. These satellite images are more useful for the variety of users for studies, analyses, planning and decision making, implementation and monitoring any portion of the Earth surface at any time.

CAPABILITY OF REMOTE SENSING

- Large aerial coverage
- Regional analysis
- Eliminate surface inaccessibility
- Provides unbiased data sets and
- Images are easy to study.

Satellite Sensors

Sensors are devices which sense the reflected energy from an object. These sensors are classified as **active sensors**, **passive sensors**, **imaging sensors**, **non-imaging sensors**, **scanning sensors** and **non-scanning sensors**. Active sensors are the sensors which send its own energy and senses back the reflected energy (microwave energy, resistivity prospecting).

But, the passive sensors will sense only the reflected EMR (film in aerial cameras, and photosynthetic cells in satellites).

Imaging sensors will have camera - lens - film system (Film in aerial and satellite cameras).

The radiometer, Geiger counter etc. which record the energy in digital form or analog form is grouped under non-imaging sensors.

In scanning sensors, the sensors will capture the reflected energy line by line (Satellite Multispectral scanning).

Whereas, the aerial photographs where in photographs are taken in perspective projections are grouped under non-scanning sensors.

Digital image processing

Digital image processing is the use of computer algorithms to perform image processing on digital images. Digital image processing has the same advantages over analog image processing as digital signal processing has over analog signal processing — it allows a much wider range of algorithms to be applied to the input data, and can avoid problems such as the build-up of noise and signal distortion during processing.

The most common kind of digital image processing is digital image editing.

History

Many of the techniques of digital image processing, or digital picture processing as it was often called, were developed in the 1960s at the Jet Propulsion Laboratory, MIT, Bell Labs, University of Maryland, and a few other places, with application to satellite imagery, wirephoto standards conversion, medical imaging, videophone, character recognition, and photo enhancement. But the cost of processing was fairly high with the computing equipment of that era. In the 1970s, digital image processing proliferated, when cheaper computers and dedicated hardware became available. Images could then be processed in real time, for some dedicated problems such as television standards conversion. As general-purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and compute-intensive operations.

With the fast computers and signal processors available in the 2000s, digital image processing has become the most common form of image processing, and is generally used because it is not only the most versatile method, but also the cheapest.

Digital processing of camera images

Digital cameras generally include dedicated digital image processing chips to convert the raw data from the image sensor into a color-corrected image in a standard image file format. Images from digital cameras often receive further processing to improve their quality, a distinct advantage digital cameras have over film cameras. The digital image processing is typically done by special software programs that can manipulate the images in many ways.

Many digital cameras also enable viewing of histograms of images, as an aid for the photographer to better understand the rendered brightness range of each shot.

Uses

Digital Image Processing allows the use of much more complex algorithms for image processing, and hence can offer both more sophisticated performance at simple tasks, and the implementation of methods which would be impossible by analog means.

In particular, digital image processing is the only practical technology for:

- Classification
- Feature extraction
- Pattern recognition
- Projection and
- Multi-scale signal analysis.

Some techniques which are used in digital image processing include:

- Principal components analysis
- Independent component analysis
- Self-organizing maps
- Hidden Markov models and
- Neural networks.

Global Positioning System (GPS)

The **Global Positioning System** (**GPS**) is the only fully functional Global Navigation Satellite System (GNSS). Utilizing a constellation of at least 24 medium Earth orbit satellites that transmit precise microwave signals, the system enables a GPS receiver to determine its location, speed, direction, and time.

Developed by the United States Department of Defense, it is officially named **NAVSTAR GPS** (Contrary to popular belief, NAVSTAR is not an acronym, but simply a name given by Mr. John Walsh, a key decision maker when it came to the budget for the GPS program[1]). The satellite constellation is managed by the United States Air Force 50th Space Wing. The cost of maintaining the system is approximately US$750 million per year,[2] including the replacement of aging satellites, and research and development.

Following the shootdown of Korean Air Lines Flight 007 in 1983, President Ronald Reagan issued a directive making the system available for free for civilian use as a common good.[3] Since then, GPS has become a widely used aid to navigation worldwide, and a useful tool for map-making, land surveying, commerce, and scientific uses. GPS also provides a precise time reference used in many applications including scientific study of earthquakes, and synchronization of telecommunications networks

Simplified method of operation

A GPS receiver calculates its position by measuring the distance between itself and three or more GPS satellites. Each satellite has an atomic clock, and continually transmits messages containing the exact time, the location of the satellite (the ephemeris), and the general system health (the almanac). The receiver, using its own clock, carefully measures the reception time of each message. This gives the distance to each satellite since the signal travels at a known speed near the speed of light. Knowing the distance to at least three satellites, and their positions, the receiver computes its position using trilateration. In practice, receivers typically do not have perfectly accurate clocks, but tracking four or more satellites allows them to compute both their location and the accurate time.

Technical description

Unlaunched GPS satellite on display at the San Diego Aerospace museum

System segmentation

The current GPS consists of three major segments. These are the space segment (SS), a control segment (CS), and a user segment (US).

Space segment

The space segment (SS) comprises the orbiting GPS satellites, or Space Vehicles (SV) in GPS parlance. The GPS design originally called for 24 SVs to be distributed equally among six circular orbital planes. The orbital planes are centered on the Earth, not rotating with respect to the distant stars. The six planes have approximately 55° inclination (tilt relative to Earth's equator) and are separated by 60° right ascension of the ascending node (angle along the equator from a reference point to the orbit's intersection).

Orbiting at an altitude of approximately 20,200 kilometers (12,600 miles or 10,900 nautical miles; orbital radius of 26,600 km (16,500 mi or 14,400 NM)), each SV makes two complete orbits each sidereal day, so it passes over the same location on Earth once each day. The orbits are arranged so that at least six satellites are always within line of sight from almost everywhere on Earth's surface.

As of September 2007, there are 31 actively broadcasting satellites in the GPS constellation. The additional satellites improve the precision of GPS receiver calculations by providing redundant measurements. With the increased number of satellites, the constellation was changed to a nonuniform arrangement. Such an arrangement was shown to improve reliability and availability of the system, relative to a uniform system, when multiple satellites fail.

Control segment

The flight paths of the satellites are tracked by US Air Force monitoring stations in Hawaii, Kwajalein, Ascension Island, Diego Garcia, and Colorado Springs, Colorado, along with monitor stations operated by the National Geospatial-Intelligence Agency (NGA). The tracking information is sent to the Air Force Space Command's master control station at Schriever Air Force Base in Colorado Springs, which is operated by the 2d Space Operations Squadron (2 SOPS) of the United States Air Force (USAF). 2 SOPS contacts each GPS satellite regularly with a navigational update (using the ground antennas at Ascension Island, Diego Garcia, Kwajalein, and Colorado Springs). These updates synchronize the atomic clocks on board the satellites to within a few nanoseconds of each other, and adjust the ephemeris of each satellite's internal orbital model. The updates are created by a Kalman filter which uses inputs from the ground monitoring stations, space weather information, and various other inputs.

GPS receivers come in a variety of formats, from devices integrated into cars, phones, and watches, to dedicated devices such as those shown here from manufacturers Trimble, Garmin and Leica (left to right).

User segment

SiRFstar III receiver and integrated antenna from UK company Antenova. This measures just 49 x 9 x 4mm.

The user's GPS receiver is the user segment (US) of the GPS system. In general, GPS receivers are composed of an antenna, tuned to the frequencies transmitted by the satellites, receiver-processors, and a highly-stable clock (often a crystal oscillator). They may also include a display for providing location and speed information to the user. A receiver is often described by its number of channels: this signifies how many satellites it can monitor simultaneously. Originally limited to four or five, this has progressively increased over the years so that, as of 2006, receivers typically have between twelve and twenty channels.

A typical OEM GPS receiver module, based on the SiRF Star III chipset, measuring 15×17 mm, and used in many products.

Calculating positions

Knowing the position and the distance of a satellite indicates that the receiver is located somewhere on the surface of an imaginary sphere centered on that satellite and whose radius is the distance to it. Receivers can substitute altitude for one satellite, which the GPS receiver translates to a pseudorange measured from the center of the earth.

Locations are calculated not in three-dimensional space, but in four-dimensional spacetime, meaning a measure of the precise time-of-day is very important. The measured pseudoranges from four satellites have already been determined with the receiver's internal clock, and thus have an unknown amount of clock error. The four-dimensional point that is equidistant from the pseudoranges is calculated as a guess as to the receiver's location, and the factor used to adjust those pseudoranges to intersect at that four-dimensional point gives a guess as to the receiver's clock offset. With each guess, a *geometric dilution of precision* (GDOP) vector is calculated, based on the relative sky positions of the satellites used. As more satellites are picked up, pseudoranges from more combinations of four satellites can be processed to add more guesses to the location and clock offset. The receiver then determines which combinations to use and how to calculate the estimated position by determining the weighted average of these positions and clock offsets. After the final location and time are calculated, the location is expressed in a specific coordinate system, e.g. latitude/longitude, using the WGS 84 geodetic datum or a local system specific to a country.

Applications

The Global Positioning System, while originally a military project, is considered a *dual-use* technology, meaning it has significant applications for both the military and the civilian industry.

Military

The military use GPS for the following purposes:

Navigation

GPS allows soldiers to find objectives in the dark or in unfamiliar territory, and to coordinate the movement of troops and supplies. The GPS-receivers commanders and soldiers use are respectively called the **Commanders Digital Assistant** and the **Soldier Digital Assistant**.

Fleet Management

Fleet management is the management of a company's vehicle fleet. A combination of GPS and radio communications can enable real-time vehicle tracking, for a variety of purposes.

Target tracking

Various military weapons systems use GPS to track potential ground and air targets before they are flagged as hostile. These weapons systems pass GPS co-ordinates of targets to precision-guided munitions to allow them to engage the targets accurately.

Military aircraft, particularly those used in air-to-ground roles use GPS to find targets (for example, gun camera video from AH-1 Cobras in Iraq show GPS co-ordinates that can be looked up in Google Earth).

Missile and projectile guidance

GPS allows accurate targeting of various military weapons including ICBMs, cruise missiles and precision-guided munitions.

Artillery projectiles with embedded GPS receivers able to withstand forces of 12,000G have been developed for use in 155 mm howitzers.

Search and Rescue

Downed pilots can be located faster if they have a GPS receiver.

Reconnaissance and Map Creation

The military use GPS extensively to aid mapping and reconnaissance.

Other

The GPS satellites also carry nuclear detonation detectors, which form a major portion of the United States Nuclear Detonation Detection System.

Civilian

This antenna is mounted on the roof of a hut containing a scientific experiment needing precise timing.

Many civilian applications benefit from GPS signals, using one or more of three basic components of the GPS: absolute location, relative movement, and time transfer.

The ability to determine the receiver's absolute location allows GPS receivers to perform as a surveying tool or as an aid to navigation. The capacity to determine relative movement enables a receiver to calculate local velocity and orientation, useful in vessels or observations of the Earth. Being able to synchronize clocks to exacting standards enables time transfer, which is critical in large communication and observation systems. An example is CDMA digital cellular. Each base station has a GPS timing receiver to synchronize its spreading codes with other base stations to facilitate inter-cell hand off and support hybrid GPS/CDMA positioning of mobiles for emergency calls and other applications.

Finally, GPS enables researchers to explore the Earth environment including the atmosphere, ionosphere and gravity field. GPS survey equipment has revolutionized tectonics by directly measuring the motion of faults in earthquakes.

Satellite numbers

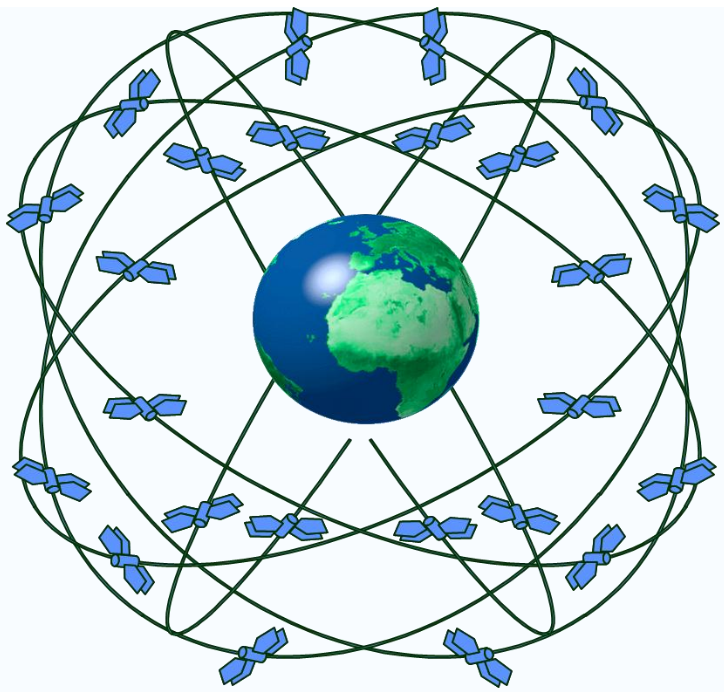
Name	Launch Period	No of satellites launched, inc. launch failures	Currently in service
Block I	1978-1985	11	0
Block II	1985-1990	9	0
Block IIA	1990-1997	19	15+1[1]
Block IIR	1997-2004	12	12
Block IIR-M	2005-	4	4
Block IIF	2008-	0	0
Total		54 (plus one not launched)	30+1
[1]One test satellite			

Other systems

Other satellite navigation systems in use or various states of development include:

- Ivan Getting, emeritus president of The Aerospace Corporation and engineer at the Massachusetts Institute of Technology, established the basis for GPS, improving on the World War II land-based radio system called LORAN (**Lo**ng-range **R**adio **A**id to **N**avigation).
- **Beidou —** China's regional system that China has proposed to expand into a global system named **COMPASS**.

- **Galileo** — a proposed global system being developed by the European Union, joined by China, Israel, India, Morocco, Saudi Arabia, South Korea, and Ukraine, planned to be operational by 2011–12.
- **GLONASS** — Russia's global system which is being restored to full availability in partnership with India.
- **Indian Regional Navigational Satellite System (IRNSS)** — India's proposed regional system nearing completion stage of all satellite launches.
- **QZSS** - Japanese proposed regional system, adding better coverage to the Japanese islands.



- 24 Satellites
- 6 Orbital Planes
- 55º Inclination to the Equator
- 20,200 km above Earth
- 12 hour orbits

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Unit- 5 Geoinformatics

Geoinformatics is a science which develops and uses information science infrastructure to address the problems of geosciences and related branches of engineering. Geoinformatics combines geospatial analysis and modeling, development of geospatial databases, information systems design, human-computer interaction and both wired and wireless networking technologies.

Geoinformatics technologies include geographic information systems, spatial decision support systems, global positioning systems (GPS), and remote sensing. Geoinformatics uses geocomputation for analyzing geoinformation.

Geoinformatics tools include:

- An object-relational database (ORD) or object-relational database management system (ORDBMS)
- Object-relational mapping (or O/RM)
- Geostatistics.

Applications

Many fields benefit from geoinformatics, including the development of in-car navigation systems, automatic vehicle location systems, transportation planning and engineering, evironmental modeling and analysis, urban planning, telecommunications, agriculture, farming, and public health, to name just a few.

Information science (also **information studies**) is an interdisciplinary science primarily concerned with the collection, classification, manipulation, storage, retrieval and dissemination of information.[1] Information science studies the application and usage of knowledge in organizations, and the interaction between people, organizations and information systems. It is often (mistakenly) considered a branch of computer science. It is actually a broad, interdisciplinary field, incorporating not only aspects of computer science, but also library science, cognitive science, and the social sciences.

Earth science (also known as **geoscience**, **the geosciences** or **the Earth Sciences**), is an all-embracing term for the sciences related to the planet Earth[1]. It is arguably a special case in planetary science, the Earth being the only known life-bearing planet. There are both reductionist and holistic approaches to Earth science. The major historic disciplines use physics, geology, geography, meteorology, mathematics, chemistry and biology to build a quantitative understanding of the principal areas or *spheres* of the Earth system

Geographic information system (GIS)

A **geographic information system (GIS)**, also known as a **geographical information system**, is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the Earth.

In the strictest sense, it is an information system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations. **Geographic information science** is the science underlying the geographic concepts, applications and systems, taught in degree and GIS Certificate programs at many universities.

Geographic information system technology can be used for scientific investigations, resource management, asset management, Environmental Impact Assessment, Urban planning, cartography, criminology, history, sales, marketing, and logistics. For example, GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster, GIS might be used to find wetlands that need protection from pollution, or GIS can be used by a company to site a new business to take advantage of a previously underserved market.

Techniques used in GIS

Data creation

Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a computer-aided design (CAD) program, and geo-referencing capabilities. With the wide availability of ortho-rectified imagery (both from satellite and aerial sources), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of through the traditional method of tracing the geographic form on a separate digitizing tablet.

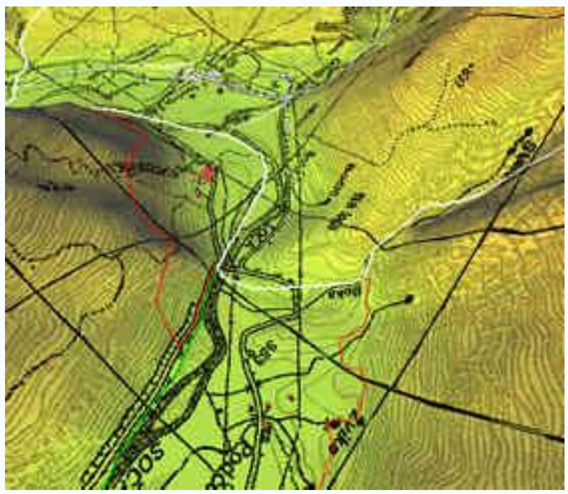
Relating information from different sources

If you could relate information about the rainfall of your state to aerial photographs of your county, you might be able to tell which wetlands dry up at certain times of the year. A GIS, which can use information from many different sources in many different forms, can help with such analyses. The primary requirement for the source data consists of knowing the locations for the variables. Location may be annotated by x, y, and z coordinates of longitude, latitude, and elevation, or by other geocode systems like ZIP Codes or by highway mile markers. Any variable that can be located spatially can be fed into a GIS. Several computer databases that can be directly entered into a GIS are being produced by government agencies and non-government organizations. Different kinds of data in map form can be entered into a GIS.

Data representation

GIS data represents real world objects (roads, land use, elevation) with digital data. Real world objects can be divided into two abstractions: discrete objects (a house) and continuous fields (rain fall amount or elevation). There are two broad methods used to store data in a GIS for both abstractions: Raster and Vector.

Raster

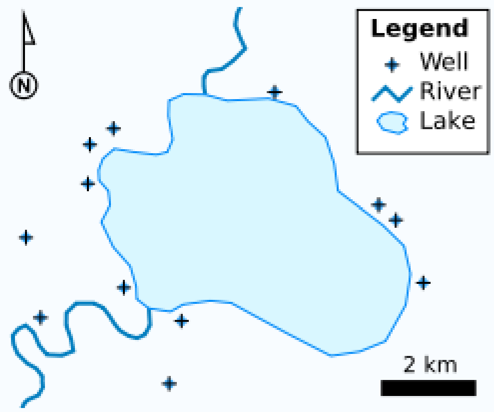


Digital elevation model, map (image), and vector data

Raster data type consists of rows and columns of cells where in each cell is stored a single value. Raster data can be images (raster images) with each pixel (or cell) containing a color value. Additional values recorded for each cell may be a discrete value, such as land use, a continuous value, such as temperature, or a null value if no data is available. While a raster cell stores a single value, it can be extended by using raster bands to represent RGB (red, green, blue) colors, colormaps (a mapping between a thematic code and RGB value), or an extended attribute table with one row for each unique cell value. The resolution of the raster data set is its cell width in ground units.

Raster data is stored in various formats; from a standard file-based structure of TIF, JPEG, etc. to binary large object (BLOB) data stored directly in a relational database management system (RDBMS) similar to other vector-based feature classes. Database storage, when properly indexed, typically allows for quicker retrieval of the raster data but can require storage of millions of significantly-sized records.

Vector



A simple vector map, using each of the vector elements: points for wells, lines for rivers, and a polygon for the lake.

In a GIS, geographical features are often expressed as vectors, by considering those features as geometrical shapes. In the popular ESRI Arc series of programs, these are explicitly called shapefiles. Different geographical features are best expressed by different types of geometry:

Points

Zero-dimensional points are used for geographical features that can best be expressed by a single grid reference; in other words, simple location. For example, the locations of wells, peak elevations, features of interest or trailheads. Points convey the least amount of information of these file types.

Lines or **polylines**

One-dimensional lines or polylines are used for linear features such as rivers, roads, railroads, trails, and topographic lines.

Polygons

Two-dimensional polygons are used for geographical features that cover a particular area of the earth's surface. Such features may include lakes, park boundaries, buildings, city boundaries, or land uses. Polygons convey the most amount of information of the file types.

Each of these geometries are linked to a row in a database that describes their attributes. For example, a database that describes lakes may contain the lakes depth, water quality, pollution level. This information can be used to make a map to describe a particular attribute of the dataset. For example, lakes could be coloured depending on level of pollution. Different geometries can also be compared. For example, the GIS could be used to identify all wells (point geometry) that are within 1 mile of a lake (polygon geometry) that has a high level of pollution.

Vector features can be made to respect spatial integrity through the application of topology rules such as 'polygons must not overlap'. Vector data can also be used to represent continuously varying phenomena. Contour lines and triangulated irregular networks (TIN) are used to represent elevation or other continuously changing values. TINs record values at point locations, which are connected by lines to form an irregular mesh of triangles. The face of the triangles represent the terrain surface.

Advantages and disadvantages

There are advantages and disadvantages to using a raster or vector data model to represent reality. Raster data sets record a value for all points in the area covered which may require more storage space than representing data in a vector format that can store data only where needed. Raster data also allows easy implementation of overlay operations, which are more difficult with vector data. Vector data can be displayed as vector graphics used on traditional maps, whereas raster data will appear as an image that may have a blocky appearance for object boundaries. Vector data can be easier to register, scale, and re-project. This can simplify combining vector layers from different sources. Vector data are more compatible with relational database environment. They can be part of a relational table as a normal column and processes using a multitude of operators.

Non-spatial data

Additional non-spatial data can also be stored besides the spatial data represented by the coordinates of a vector geometry or the position of a raster cell. In vector data, the additional data are attributes of the object. For example, a forest inventory polygon may also have an identifier value and information about tree species. In raster data the cell value can store attribute information, but it can also be used as an identifier that can relate to records in another table.

Data capture - sources

Data capture—entering information into the system—consumes much of the time of GIS practitioners. There are a variety of methods used to enter data into a GIS where it is stored in a digital format.

Existing data printed on paper or PET film maps can be digitized or scanned to produce digital data. A digitizer produces vector data as an operator traces points, lines, and polygon boundaries from a map. Scanning a map using scanner is resulting in raster data that could be further processed to produce vector data.

Survey data can be directly entered into a GIS from digital data collection systems on survey instruments. Positions from a Global Positioning System (GPS), another survey tool, can also be directly entered into a GIS.

Remotely sensed data also plays an important role in data collection and consist of sensors attached to a platform. Sensors include cameras, digital scanners and LIDAR, while platforms usually consist of aircraft and satellites.

The majority of digital data currently comes from photo interpretation of aerial photographs. Soft copy workstations are used to digitize features directly from stereo pairs of digital photographs. These systems allow data to be captured in 2 and 3 dimensions, with elevations measured directly from a stereo pair using principles of photogrammetry. Currently, analog aerial photos are scanned before being entered into a soft copy system, but as high quality digital cameras become cheaper this step will be skipped.

Satellite remote sensing provides another important source of spatial data. Here satellites use different sensor packages to passively measure the reflectance from parts of the electromagnetic spectrum or radio waves that were sent out from an active sensor such as radar. Remote sensing collects raster data that can be further processed to identify objects and classes of interest, such as land cover.

When data is captured, the user should consider if the data should be captured with either a relative accuracy or absolute accuracy, since this could not only influence how information will be interpreted but also the cost of data capture.

In addition to collecting and entering spatial data, attribute data is also entered into a GIS. For vector data, this includes additional information about the objects represented in the system.

After entering data into a GIS, the data usually requires editing, to remove errors, or further processing. For vector data it must be made "topologically correct" before it can be used for some advanced analysis. For example, in a road network, lines must connect with nodes at an intersection. Errors such as undershoots and overshoots must also be removed. For scanned maps, blemishes on the source map may need to be removed from the resulting raster. For example, a fleck of dirt might connect two lines that should not be connected.

Raster-to-vector translation or Conversion

Data restructuring can be performed by a GIS to convert data into different formats. For example, a GIS may be used to convert a satellite image map to a vector structure by generating lines around all cells with the same classification, while determining the cell spatial relationships, such as adjacency or inclusion.

More advanced data processing can occur with image processing, a technique developed in the late 1960s by NASA and the private sector to provide contrast enhancement, false colour rendering and a variety of other techniques including use of two dimensional Fourier transforms.

Since digital data are collected and stored in various ways, the two data sources may not be entirely compatible. So a GIS must be able to convert geographic data from one structure to another.

Projections, co-ordinate systems and registration

A property ownership map and a soils map might show data at different scales. Map information in a GIS must be manipulated so that it registers, or fits, with information gathered from other maps. Before the digital data can be analyzed, they may have to undergo other manipulations—projection and coordinate conversions, for example—that integrate them into a GIS.

The earth can be represented by various models, each of which may provide a different set of coordinates (e.g., latitude, longitude, elevation) for any given point on the earth's surface. The simplest model is to assume the earth is a perfect sphere. As more measurements of the earth have accumulated, the models of the earth have become more sophisticated and more accurate. In fact, there are models that apply to different areas of the earth to provide increased accuracy (e.g., North American Datum, 1927 - NAD27 - works well in North America, but not in Europe). See Datum for more information.

Projection is a fundamental component of map making. A projection is a mathematical means of transferring information from a model of the Earth, which represents a three-dimensional curved surface, to a two-dimensional medium—paper or a computer screen. Different projections are used for different types of maps because each projection particularly suits certain uses. For example, a projection that accurately represents the shapes of the continents will distort their relative sizes. See Map projection for more information.

Since much of the information in a GIS comes from existing maps, a GIS uses the processing power of the computer to transform digital information, gathered from sources with different projections and/or different coordinate systems, to a common projection and coordinate system. For images, this process is called rectification.

Spatial analysis with GIS

Data modeling

It is difficult to relate wetlands maps to rainfall amounts recorded at different points such as airports, television stations, and high schools. A GIS, however, can be used to depict two- and three-dimensional characteristics of the Earth's surface, subsurface, and atmosphere from information points. For example, a GIS can quickly generate a map with isopleth or contour lines that indicate differing amounts of rainfall.

Such a map can be thought of as a rainfall contour map. Many sophisticated methods can estimate the characteristics of surfaces from a limited number of point measurements. A two-dimensional contour map created from the surface modeling of rainfall point measurements may be overlaid and analyzed with any other map in a GIS covering the same area.

Additionally, from a series of three-dimensional points, or digital elevation model, isopleth lines representing elevation contours can be generated, along with slope analysis, shaded relief, and other elevation products. Watersheds can be easily defined for any given reach, by computing all of the areas contiguous and uphill from any given point of interest. Similarly, an expected thalweg of where surface water would want to travel in intermittent and permanent streams can be computed from elevation data in the GIS.

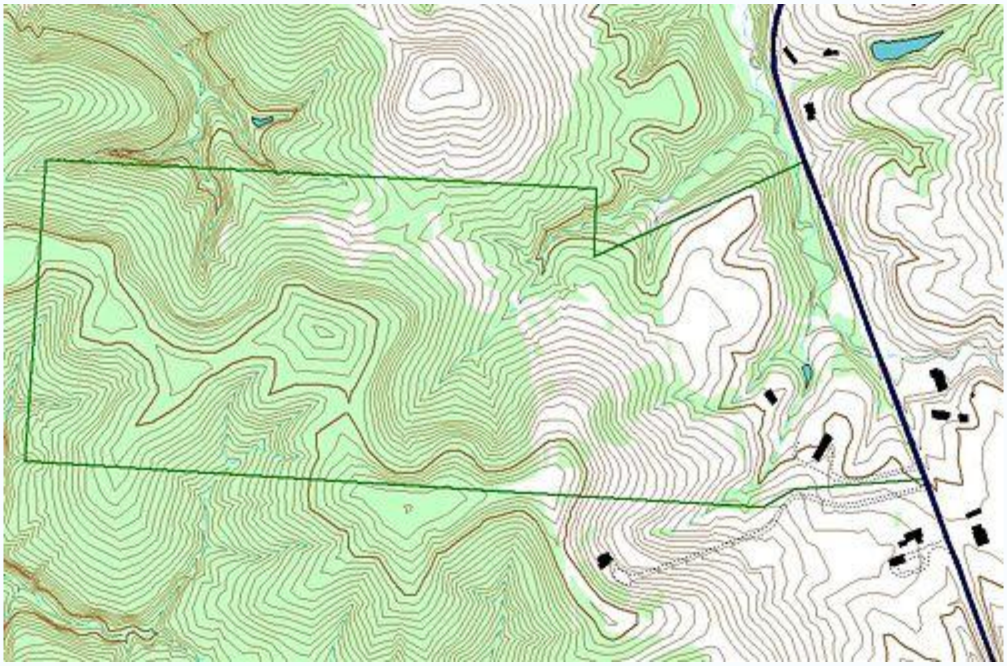
Topological modeling

In the past years, were there any gas stations or factories operating next to the swamp? Any within two miles and uphill from the swamp? A GIS can recognize and analyze the spatial relationships that exist within digitally stored spatial data. These topological relationships allow complex spatial modelling and analysis to be performed. Topological relationships between geometric entities traditionally include adjacency (what adjoins what), containment (what encloses what), and proximity (how close something is to something else).

Networks

If all the factories near a wetland were accidentally to release chemicals into the river at the same time, how long would it take for a damaging amount of pollutant to enter the wetland reserve? A GIS can simulate the routing of materials along a linear network. Values such as slope, speed limit, or pipe diameter can be incorporated into network modeling in order to represent the flow of the phenomenon more accurately. Network modelling is commonly employed in transportation planning, hydrology modeling, and infrastructure modeling.

Cartographic modeling



An example of use of layers in a GIS application. In this example, the forest cover layer (light green) is at the bottom, with the topographic layer over it. Next up is the stream layer, then the boundary layer, then the road layer. The order is very important in order to properly display the final result. Note that the pond layer was located just below the stream layer, so that a stream line can be seen overlying one of the ponds.

The term "cartographic modeling" was (probably) coined by Dana Tomlin in his PhD dissertation and later in his book which has the term in the title. Cartographic modeling refers to a process where several thematic layers of the same area are produced, processed, and analyzed. Tomlin used raster layers, but the overlay method (see below) can be used more generally. Operations on map layers can be combined into algorithms, and eventually into simulation or optimization models.

Map overlay

The combination of two separate spatial data sets (points, lines or polygons) to create a new output vector data set is called as map overlay. These overlays are similar to mathematical Venn diagram overlays. A union overlay combines the geographic features and attribute tables of both inputs into a single new output. An intersect overlay defines the area where both inputs overlap and retains a set of attribute fields for each. A symmetric difference overlay defines an output area that includes the total area of both inputs except for the overlapping area.

Data extraction is a GIS process similar to vector overlay, though it can be used in either vector or raster data analysis. Rather than combining the properties and features of both data sets, data extraction involves using a "clip" or "mask" to extract the features of one data set that fall within the spatial extent of another data set.

In raster data analysis, the overlay of data sets is accomplished through a process known as "local operation on multiple rasters" or "map algebra," through a function that combines the values of each raster's matrix. This function may weigh some inputs more than others through use of an "index model" that reflects the influence of various factors upon a geographic phenomenon.

Automated cartography

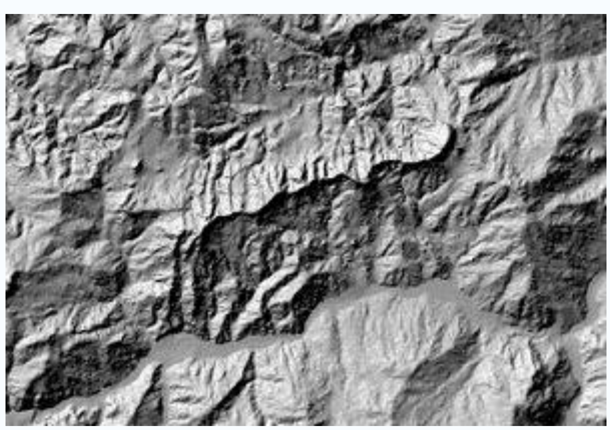
Digital cartography and GIS both encode spatial relationships in structured formal representations. GIS is used in digital cartography modeling as a (semi)automated process of making maps, so called Automated Cartography. In practice, it can be a subset of a GIS, within which it is equivalent to the stage of visualization, since in most cases not all of the GIS functionality is used. Cartographic products can be either in a digital or in a hardcopy format. Powerful analysis techniques with different data representation can produce high-quality maps within a short time period. The main problem in Automated Cartography is to use a single set of data to produce multiple products at a variety of scales, a technique known as Generalization.

Geostatistics

Geostatistics is a point-pattern analysis that produces field predictions from data points. It is a way of looking at the statistical properties of those special data. It is different from general applications of statistics because it employs the use of graph theory and matrix algebra to reduce the number of parameters in the data. Only the second-order properties of the GIS data are analyzed.

When phenomena are measured, the observation methods dictate the accuracy of any subsequent analysis. Due to the nature of the data (e.g. traffic patterns in an urban environment; weather patterns over the Pacific Ocean), a constant or dynamic degree of precision is always lost in the measurement. This loss of precision is determined from the scale and distribution of the data collection.

To determine the statistical relevance of the analysis, an average is determined so that points (gradients) outside of any immediate measurement can be included to determine their predicted behavior. This is due to the limitations of the applied statistic and data collection methods, and interpolation is required in order to predict the behavior of particles, points, and locations that are not directly measurable.



Hillshade model derived from a Digital Elevation Model (DEM) of the Valestra area in the northern Apennines (Italy)

Interpolation is the process by which a surface is created, usually a raster data set, through the input of data collected at a number of sample points. There are several forms of interpolation, each which treats the data differently, depending on the properties of the data set. In comparing interpolation methods, the first consideration should be whether or not the source data will change (exact or approximate). Next is whether the method is subjective, a human interpretation, or objective. Then there is the nature of transitions between points: are they abrupt or gradual. Finally, there is whether a method is global (it uses the entire data set to form the model), or local where an algorithm is repeated for a small section of terrain.

Interpolation is a justified measurement because of a Spatial Autocorrelation Principle that recognizes that data collected at any position will have a great similarity to, or influence of those locations within its immediate vicinity.

Digital elevation models (DEM), triangulated irregular networks (TIN), Edge finding algorithms, Theissen Polygons, Fourier analysis, Weighted moving averages, Inverse Distance Weighted, Moving averages, Kriging, Spline, and Trend surface analysis are all mathematical methods to produce interpolative data.

Data output and cartography

Cartography is the design and production of maps, or visual representations of spatial data. The vast majority of modern cartography is done with the help of computers, usually using a GIS. Most GIS software gives the user substantial control over the appearance of the data.

Cartographic work serves two major functions:

First, it produces graphics on the screen or on paper that convey the results of analysis to the people who make decisions about resources. Wall maps and other graphics can be generated, allowing the viewer to visualize and thereby understand the results of analyses or simulations of potential events. Web Map Servers facilitate distribution of generated maps through web browsers using various implementations of web-based application programming interfaces(AJAX, Java, Flash, etc).

Second, other database information can be generated for further analysis or use. An example would be a list of all addresses within one mile of a toxic spill.

Graphic display techniques

Traditional maps are abstractions of the real world, a sampling of important elements portrayed on a sheet of paper with symbols to represent physical objects. People who use maps must interpret these symbols. Topographic maps show the shape of land surface with contour lines; the actual shape of the land can be seen only in the mind's eye.

Today, graphic display techniques such as shading based on altitude in a GIS can make relationships among map elements visible, heightening one's ability to extract and analyze information. For example, two types of data were combined in a GIS to produce a perspective view of a portion of San Mateo County, California.

- The digital elevation model, consisting of surface elevations recorded on a 30-meter horizontal grid, shows high elevations as white and low elevation as black.
- The accompanying Landsat Thematic Mapper image shows a false-color infrared image looking down at the same area in 30-meter pixels, or picture elements, for the same coordinate points, pixel by pixel, as the elevation information.

A GIS was used to register and combine the two images to render the three-dimensional perspective view looking down the San Andreas Fault, using the Thematic Mapper image pixels, but shaded using the elevation of the landforms. The GIS display depends on the viewing point of the observer and time of day of the display, to properly render the shadows created by the sun's rays at that latitude, longitude, and time of day.

GIS software

Geographic information can be accessed, transferred, transformed, overlaid, processed and displayed using numerous software applications. Within industry commercial offerings from companies such as ESRI and Mapinfo dominate, offering an entire suite of tools. Government and military departments often use custom software, open source products, such as GRASS, or more specialized products that meet a well defined need. Although free tools exist to view GIS datasets, public access to geographic information is dominated by online resources such as Google Earth and interactive web mapping.

Geodatabases

A geodatabase is a database with extensions for storing, querying, and manipulating geographic information and spatial data.

Mobile GIS

GIS has seen many implementations on mobile devices. With the widespread adoption of GPS, GIS has been used to capture and integrate data in the field.

Free and Open-source GIS software

Many GIS tasks can be accomplished with free or open-source software.

With the broad use of non-proprietary and open data formats such as the Shape File format for vector data and the Geotiff format for raster data, as well as the adoption of Open Geospatial Consortium (OGC) protocols such as Web Mapping Service (WMS) and Web Feature Service (WFS), development of open source software continues to evolve, especially for web and web service oriented applications. Well-known open source GIS software includes GRASS GIS, Quantum GIS, MapServer, uDig, OpenJUMP, gvSIG and many others (e.g., see OSGeo or MapTools).

Much open source GIS development has focused on the creation of libraries that provide functionality for third party applications. Such libraries include GDAL/OGR, and the Open Source Java GIS toolkit. These libraries are used by Open Source and Commercial software alike to provide basic functionality.

PostGIS provides an open source alternative to geodatabases such as Oracle Spatial, and ArcSDE.

Vehicle navigation

A database model of a network of roads and related features is a form of GIS data that is used for vehicle navigation systems. Such a map database is a vector representation of a given road network including road geometry (segment shape), network topology (connectivity) and related attributes (addresses, road class, etc). Geographic Data Files (GDF) is an ISO standard for formulating map databases for navigation. An Automotive navigation system will combine map-matching, GPS coordinates, and Dead reckoning to estimate the position of the vehicle. The map database is also used for route planning and guidance, and possibly advanced functions involving active safety, driver assistance and location-based services. Maintenance of databases for vehicle navigation is discussed in the article **Map database management**.

GIS - Remote Sensing software – rate of usage

According to a NOAA Sponsored Research by Global Marketing Insights, Inc. the most used software among Asian academic groups involved in remote sensing are as follows: ESRI 30%; ERDAS 25%; RSI ENVI 17%; MapInfo 17%; ERMapper 11%. Among Western Academic respondents as follows: ESRI 39%, ERDAS 27%, MapInfo 9%, AutoDesk 7%, RSI ENVI 17%.

The future of GIS

Many disciplines can benefit from GIS technology. An active GIS market has resulted in lower costs and continual improvements in the hardware and software components of GIS. These developments will, in turn, result in a much wider use of the technology throughout science, government, business, and industry, with applications including real estate, public health, crime mapping, national defense, sustainable development, natural resources, landscape architecture, archaeology, regional and community planning, transportation and logistics. GIS is also diverging into location-based services (LBS). LBS allows GPS enabled mobile devices to display their location in relation to fixed assets (nearest restaurant, gas station, fire hydrant), mobile assets (friends, children, police car) or to relay their position back to a central server for display or other processing. These services continue to develop with the increased integration of GPS functionality with increasingly powerful mobile electronics (cell phones, PDAs, laptops).

Web mapping

In recent years there has been an explosion of mapping applications on the web such as Google Maps, and Live Maps. These websites give the public access to huge amounts of geographic data with an emphasis on aerial photography.

Some of them, like Google Maps, expose an API that enable users to create custom applications. These vendors' applications offer street maps and aerial/satellite imagery that support such features as geocoding, searches, and routing functionality.

Independent applications also exist for publishing geographic information on the web include Intergraph's GeoMedia WebMap (TM), ESRI's ArcIMS, ArcGIS Server, AutoDesk's Mapguide, SeaTrails' AtlasAlive, and the open source MapServer.

In recent years web mapping services have begun to adopt features more common in GIS. Services such as Google Maps and Live Maps allow users to annotate maps and share the maps with other. Conversely GIS vendors have also created web mapping systems such as ESRI's WebADF that adopt much of the usability and speed of consumer web mapping web sites.

Spatial Decision Support Systems (SDSS)

Spatial Decision Support Systems (SDSS) developed in parallel with the concept of Decision Support Systems (DSS).

An SDSS is an interactive, computer-based system designed to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi-structured spatial problem. It is designed to assist the spatial planner with guidance in making land use decisions. For example, when deciding where to build a new airport many contrasting criteria, such as noise pollution vs. employment prospects or the knock on effect on transportation links, which make the decision difficult. A system which models decisions could be used to help identify the most effective decision path.

An SDSS is sometimes referred to as a Policy Support System. A spatial decision support system typically consists of the following components.

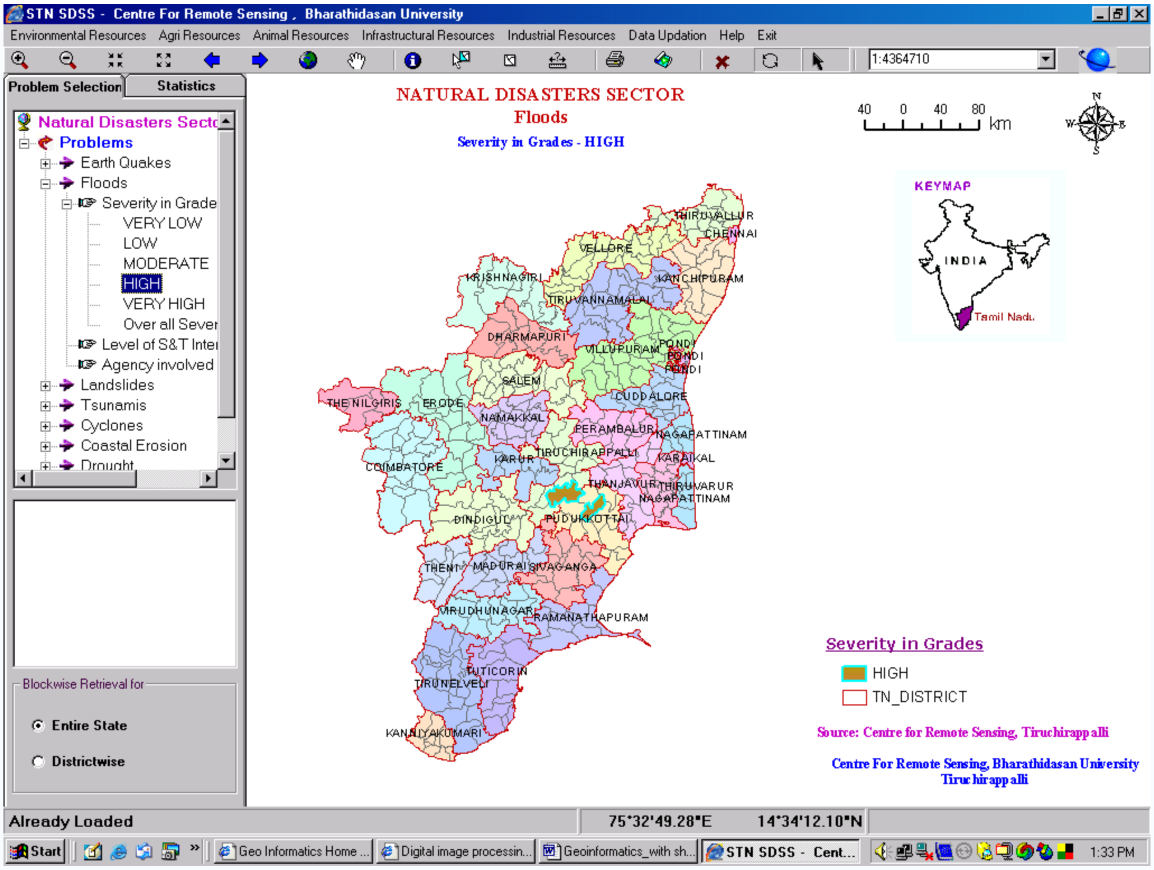
1. A database management system - This system holds and handles the geographical data. A standalone system for this is called a Geographical Information System, (GIS).

2. A library of potential models that can be used to forecast the possible outcomes of decisions.
3. An interface to aid the users interaction with the computer system and to assist in analysis of outcomes

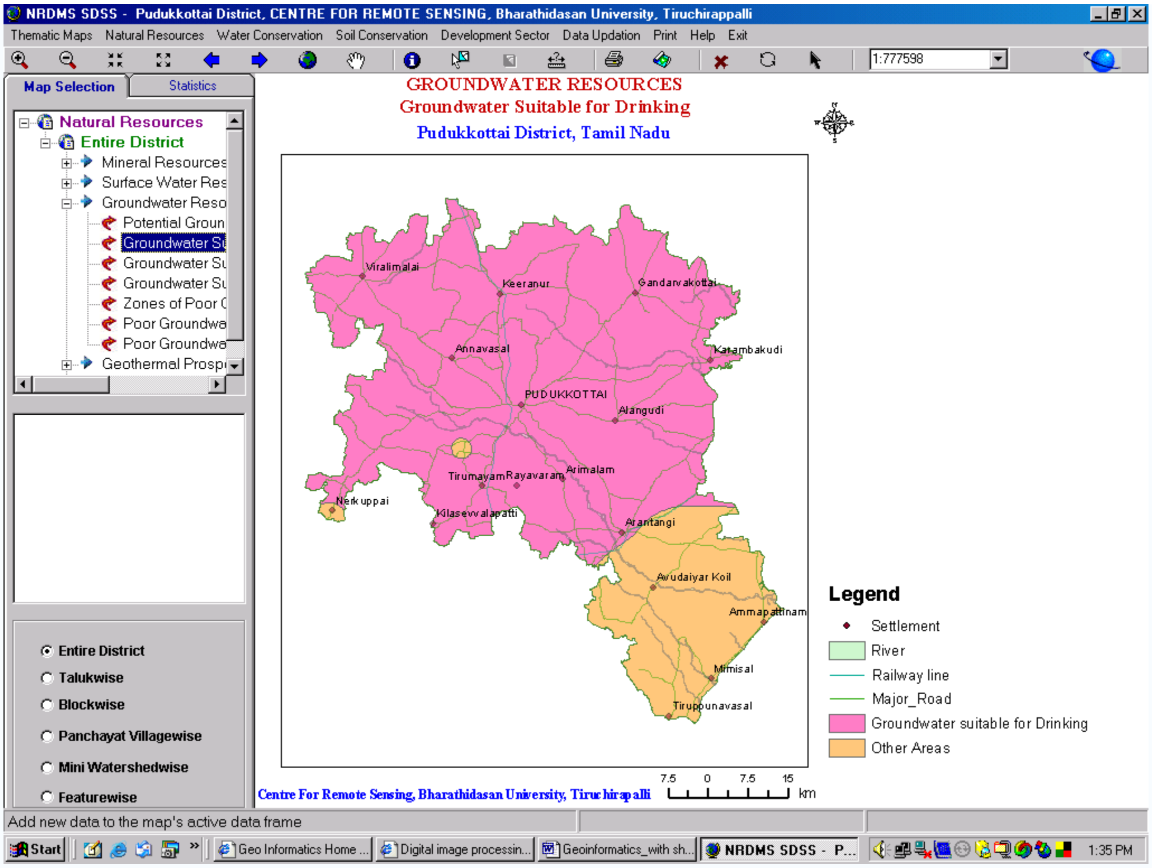
How does an SDSS work?

An sDSS usually exists in the form of a computer model or collection of interlinked computer models, including a land use model. Although various techniques are available to simulate land use dynamics, two types are particularly suitable for sDSS. These are Cellular Automata (CA) based models and Agent Based Models (ABM).

An SDSS typically uses a variety of spatial and nonspatial information, like data on land use, transportation, water management, demographics, agriculture, climate or employment. By using two (or, better, more) known points in history the models can be calibrated and then projections into the future can be made to analyze different spatial policy options. Using these techniques spatial planners can investigate the effects of different scenarios, and provide information to make informed decisions. To allow the user to easily adapt the system to deal with possible intervention possibilities an interface allows for simple modification to be made.



This above figure shows a screenshot of an SDSS namley STN-SDSS useful in making decisions by the scientists, technocrats and administrators who are non-GIS users, in understanding the Natural Disaster severity of each blocks of Tamil Nadu and also helpful to know the strategic plans that could be adopted from Science and Technology researches. This model SDSS has been developed by analysing and incorporating several Geoscientific spatial data and attribute details.



The above figure is an another SDSS (NRDMS SDSS – Natural Resources Data Management System, DST, New Delhi) developed for the use by the Collector and Higher Officials of Pudukkottai Collectorate of Tamil Nadu. In this NRDMS SDSS, more than 90 Geospatial databases have been generated in GIS along with sector wise attribute details kept readily with data linkage with Geospatial database so as to retrieve the information quickly within 2 to3 mouse clicks / touches in kiosk screen.

Examples where an SDSS has been used

CommunityViz

CommunityViz is a land-use planning SDSS that works as an extension to ArcGIS Geographic Information System software produced by ESRI. It uses a scenario planning approach and calculates economic, environmental, social and visual impacts and indicators dynamically as users explore alternatives. Interactive 3D models and various tools for public participation and collaboration are also included. It has been commercially available since 2001.

Environment Explorer

The Environment Explorer (LOV) is a spatial, dynamic model, in which land use and the effects on social, economic and ecological indicators are modeled in an integrated way. Its primary goal is to explore future developments, combining autonomous developments with alternative policy options, in relation to the quality of the environment in which inhabitants of the Netherlands live, work and recreate. Various policy options from governmental departments are translated into a spatial, dynamic image of the Netherlands future with respect to issues such as: economic activity, employment, social well-being, transportation and accessibility, and the natural environment. The model covers the whole of The Netherlands.

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Text Books:

1. Parbin Singh,2008: A text book ofg 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.
16. Web Sources.

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