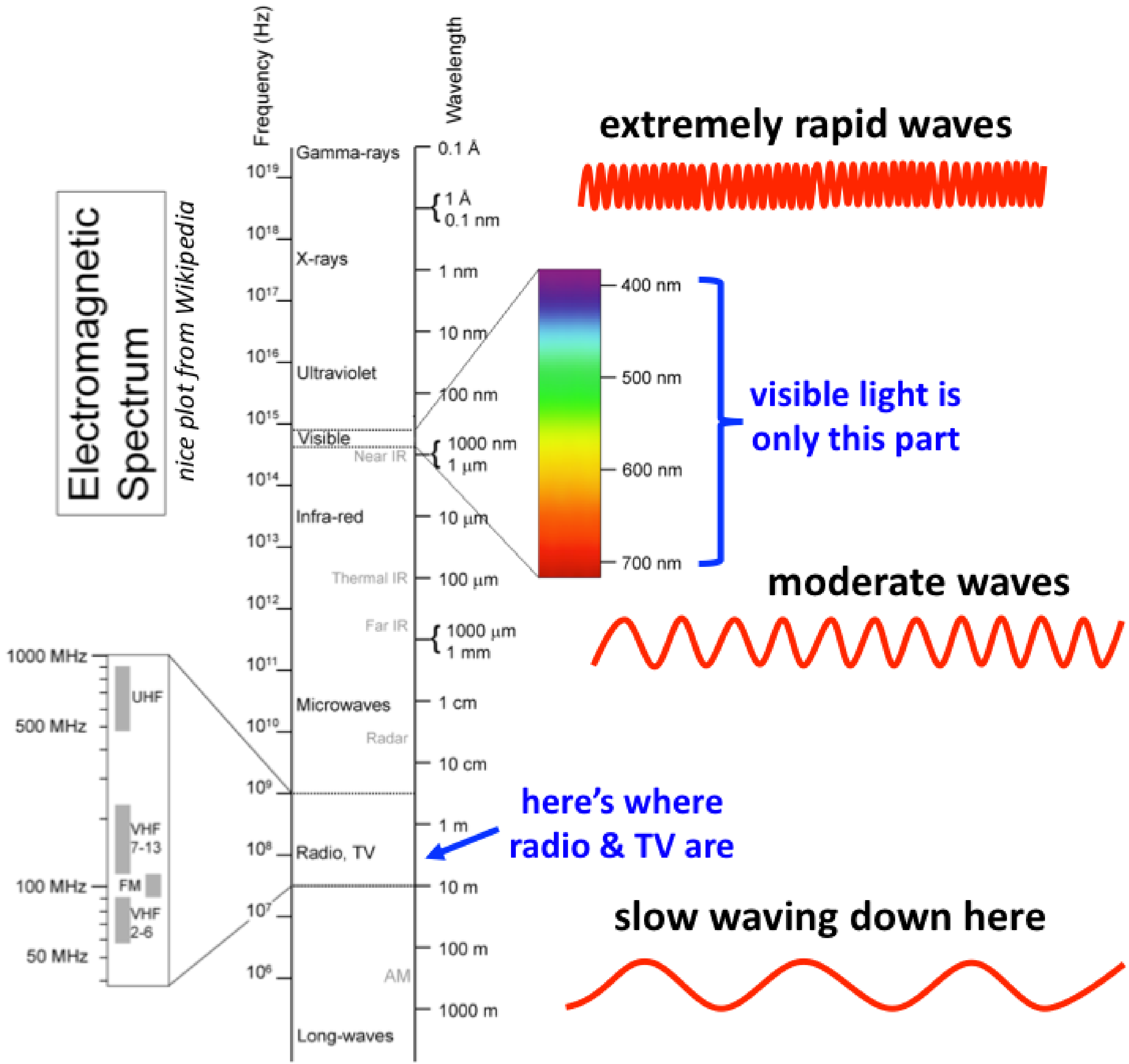
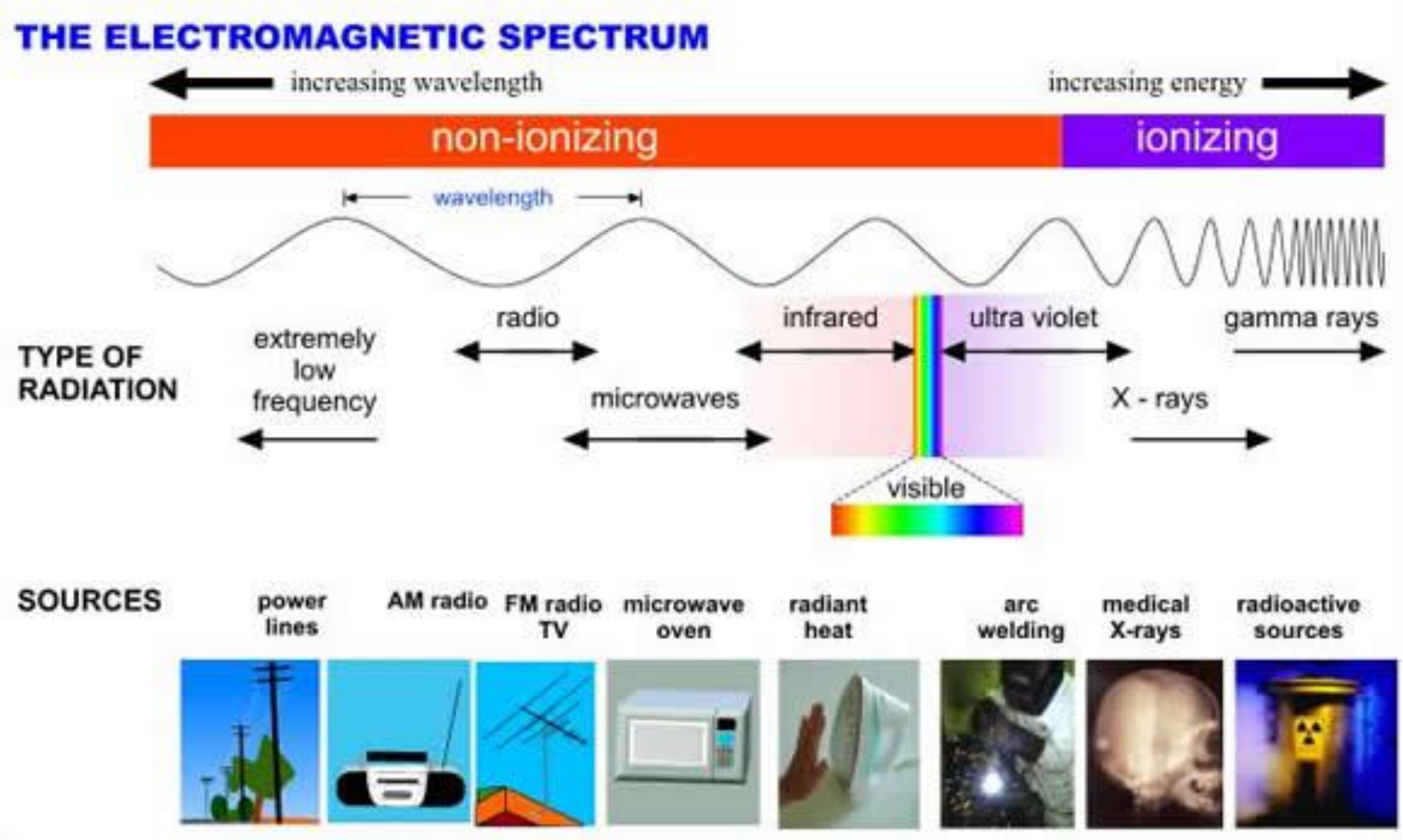
UNIT- 5

SPECTRAL PROPERTIES OF MINERALS AND ROCKS

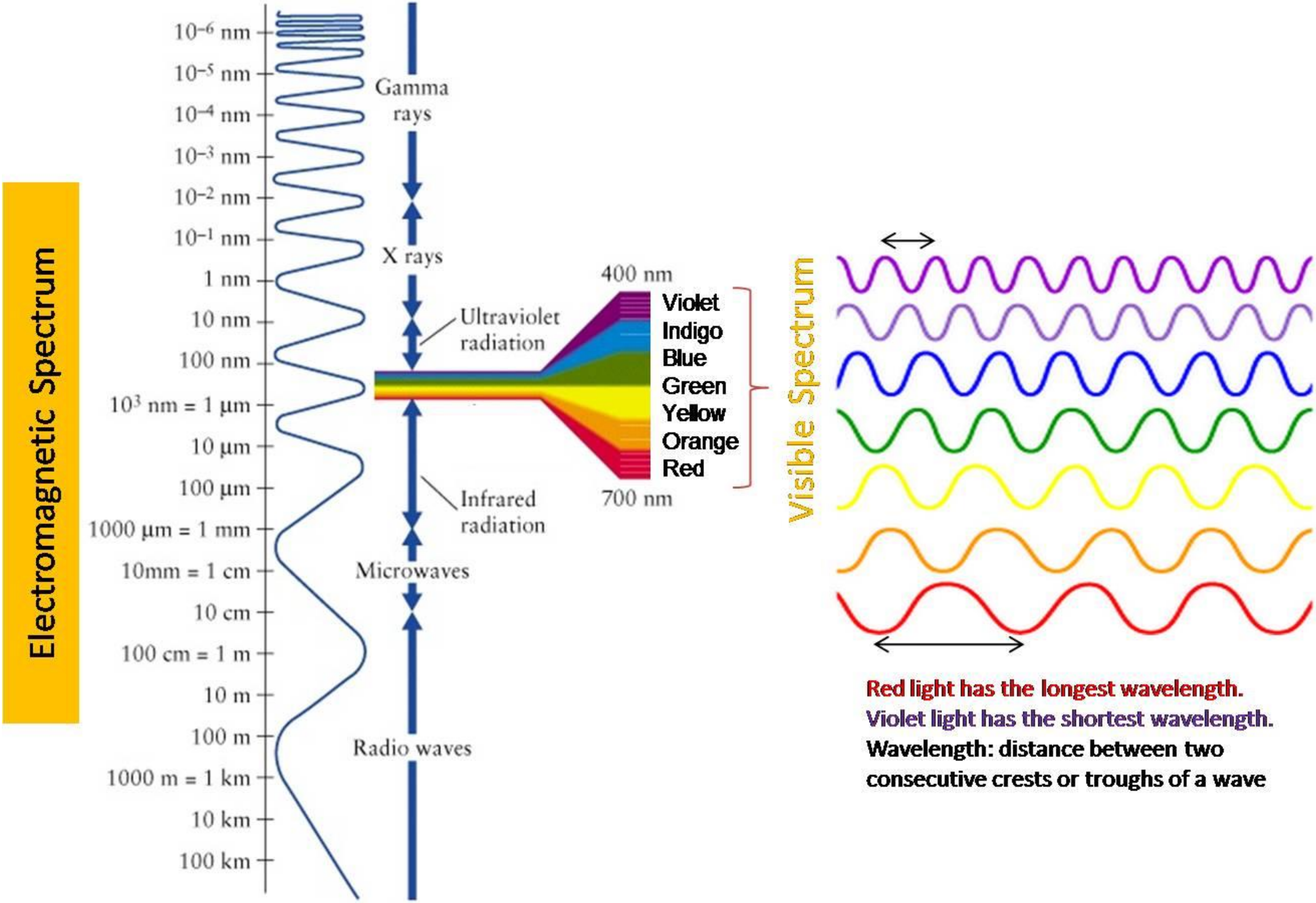
Light: Electromagnetic Radiation



waves are not drawn to scale: that would be IMPOSSIBLE!


THE ELECTROMAGNETIC SPECTRUM
increasing wavelength
increasing energy
non-ionizing
ionizing
wavelength
TYPE OF RADIATION
extremely low frequency
radio
microwaves
infrared
visible
ultra violet
X - rays
gamma rays
SOURCES
power lines
AM radio
FM radio TV
microwave oven
radiant heat
arc welding
medical X-rays
radioactive sources

shortest wavelength



longest wavelength

1. Introduction

- Spectroscopy is the study of light as a function of wavelength that has been **emitted, reflected or scattered** from a solid, liquid, or gas.

- The spectroscopy of minerals, but the principles apply to any material.

- Adams (1975), Hunt (1977), Farmer (1974), Hunt (1982); Clark and Roush (1984), Clark et al. (1990a), Gaffey et al. (1993), Salisbury (1993), and references in those papers for more details.

1.2 Absorption and Scattering.

- As photons enter a mineral, some are **reflected** from grain surfaces, some **pass through** the grain, and some are **absorbed**. Those photons that are reflected from grain surfaces or refracted through a particle are said to be scattered.

- All natural surfaces emit photons when they are above absolute zero. Emitted photons are subject to the same **physical laws of reflection, refraction, and absorption** to which incident photons are bound.

- Photons are absorbed in minerals by several processes. The variety of absorption processes and their wavelength dependence allows us to derive information about the chemistry of a mineral from its reflected or emitted light.

- **The human eye is a crude reflectance spectrometer:**

  we can look at a surface and see color. Our eyes and brain are processing the wavelength-dependent scattering of visible-light photons to reveal something about what we are observing, like the **red color of hematite** or **the green color of olivine.**

- A modern spectrometer, however, can measure finer details over a broader wavelength range and with greater precision. Thus, a spectrometer can measure absorptions due to more processes than can be seen with the eye.

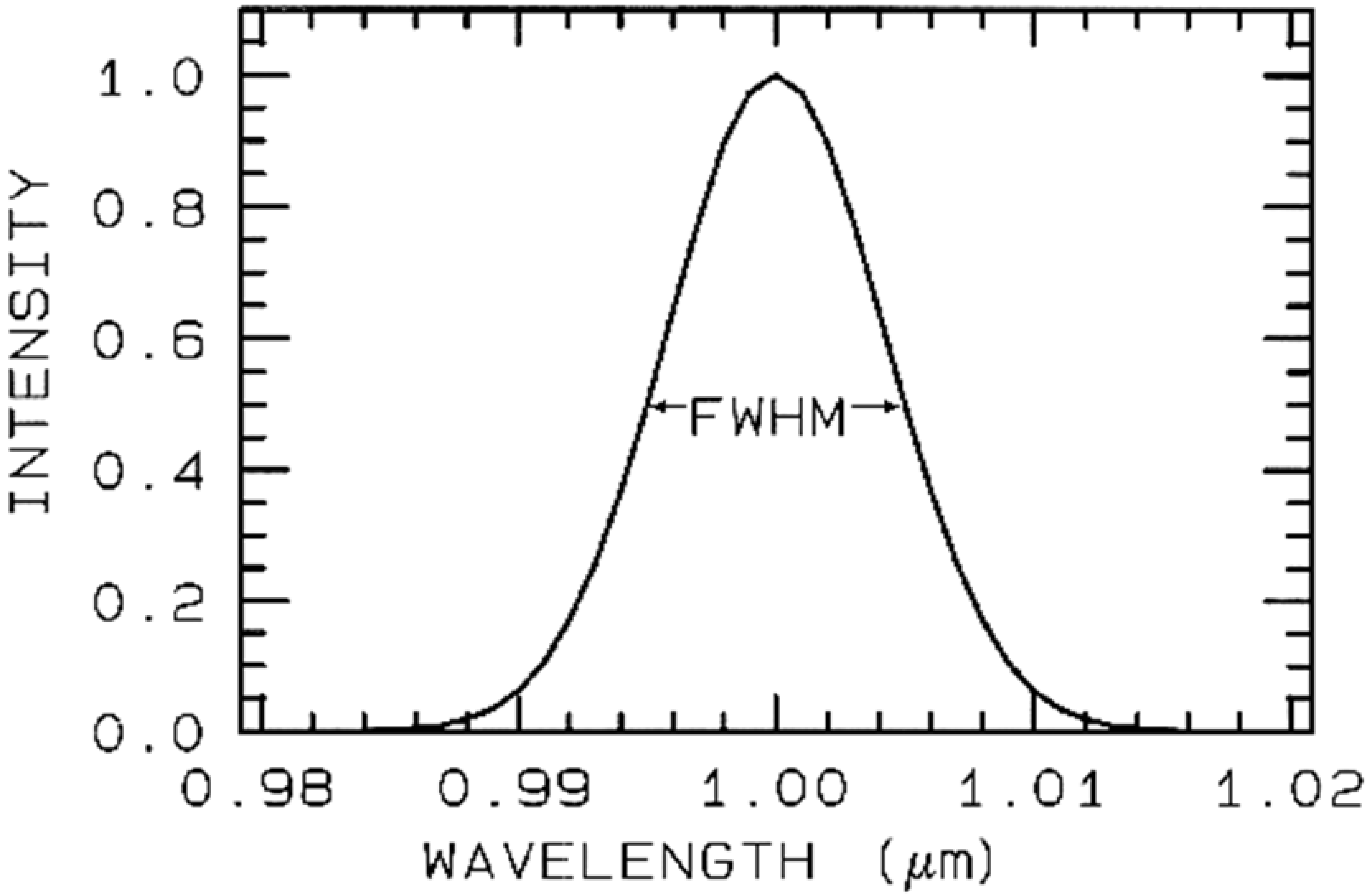
1.3 Spectroscopy Terms.

There are 4 general parameters that describe the capability of a spectrometer:

1) **Spectral range,**
2) **Spectral bandwidth,**
3) **Spectral sampling, and**
4) **Signal-to-noise ratio (S/N).**

Spectral range is important to cover enough diagnostic spectral absorptions to solve a desired problem. There are general spectral ranges that are in common use, each to first order controlled by detector technology:

a) **Ultraviolet (UV): 0.001 to 0.4 µm,**
b) **Visible: 0.4 to 0.7 µm,**
c) **Near-infrared (NIR): 0.7 to 3.0 µm,**
d) **The Mid-infrared (MIR): 3.0 to 30 µm, and**
e) **The Far infrared (FIR): 30 µm to 1 mm**



Spectral bandwidth - Full Width at Half Maximum (FWHM)

- The signal-to-noise ratio (S/N) required to solve a particular problem will depend on the strength of the spectral features under study.

- The S/N is dependent on the **detector sensitivity, the spectral bandwidth, and intensity of the light reflected or emitted** from the surface being measured.

- The ~0.4 to 1.0-µm (micro meter) wavelength range is sometimes referred to in the remote sensing literature as the **VNIR** (visible-near-infrared) and the 1.0 to 2.5-µm range is sometimes referred to as the **SWIR** (short-wave infrared).

- The **mid-infrared** covers thermally emitted energy, which for the Earth starts at about 2.5 to 3 µm, peaking near 10 µm.

- Spectral bandwidth is the width of an individual spectral channel in the spectrometer. The narrower the spectral bandwidth, the narrower the absorption feature the spectrometer will accurately measure, if enough adjacent spectral samples are obtained.

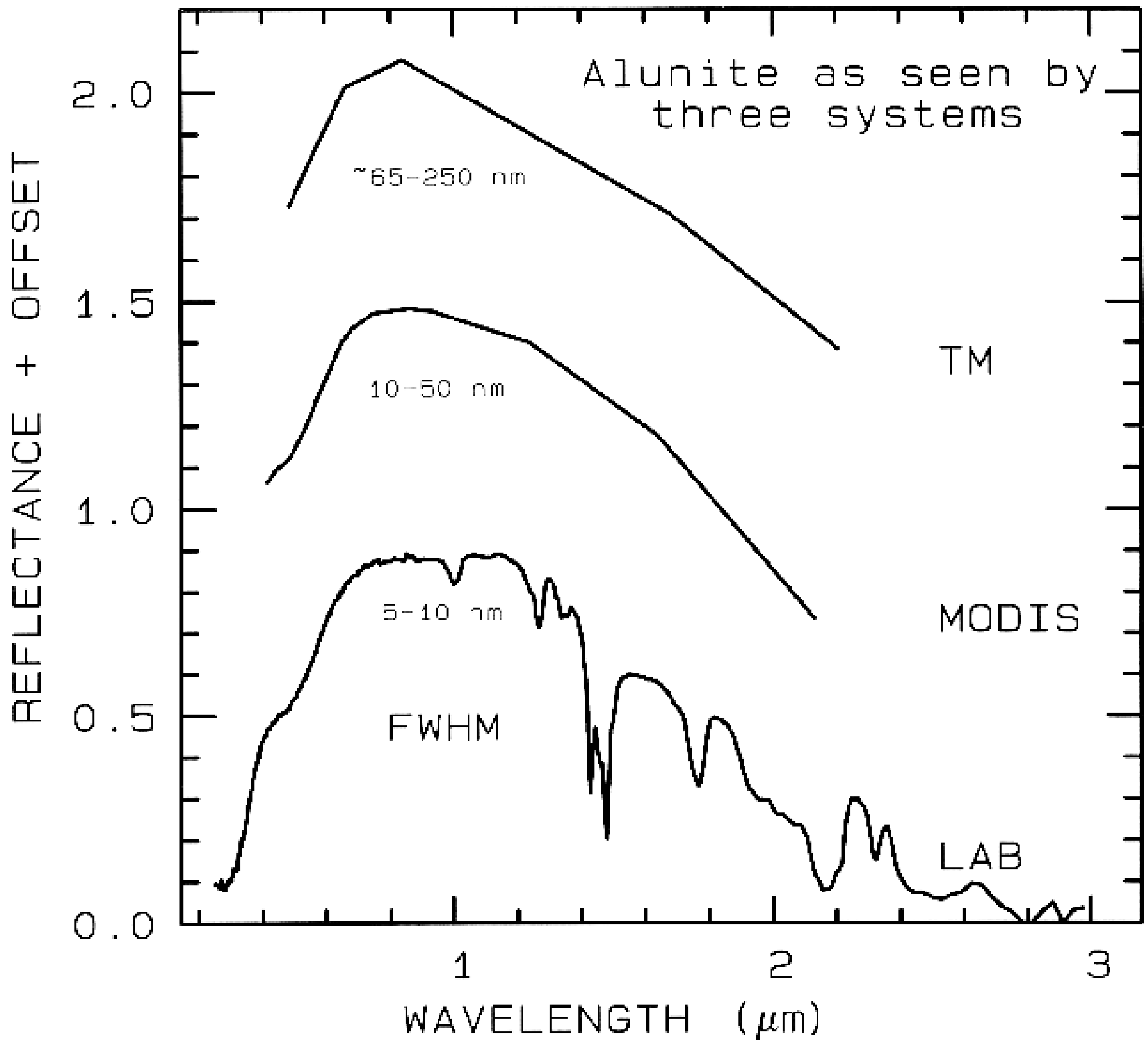


Figure 1a. Spectra of the mineral alunite is shown as measured in the laboratory and for broad-band remote sensing instruments.

Each spectrum is offset upward 0.6 units from the one below it for clarity.

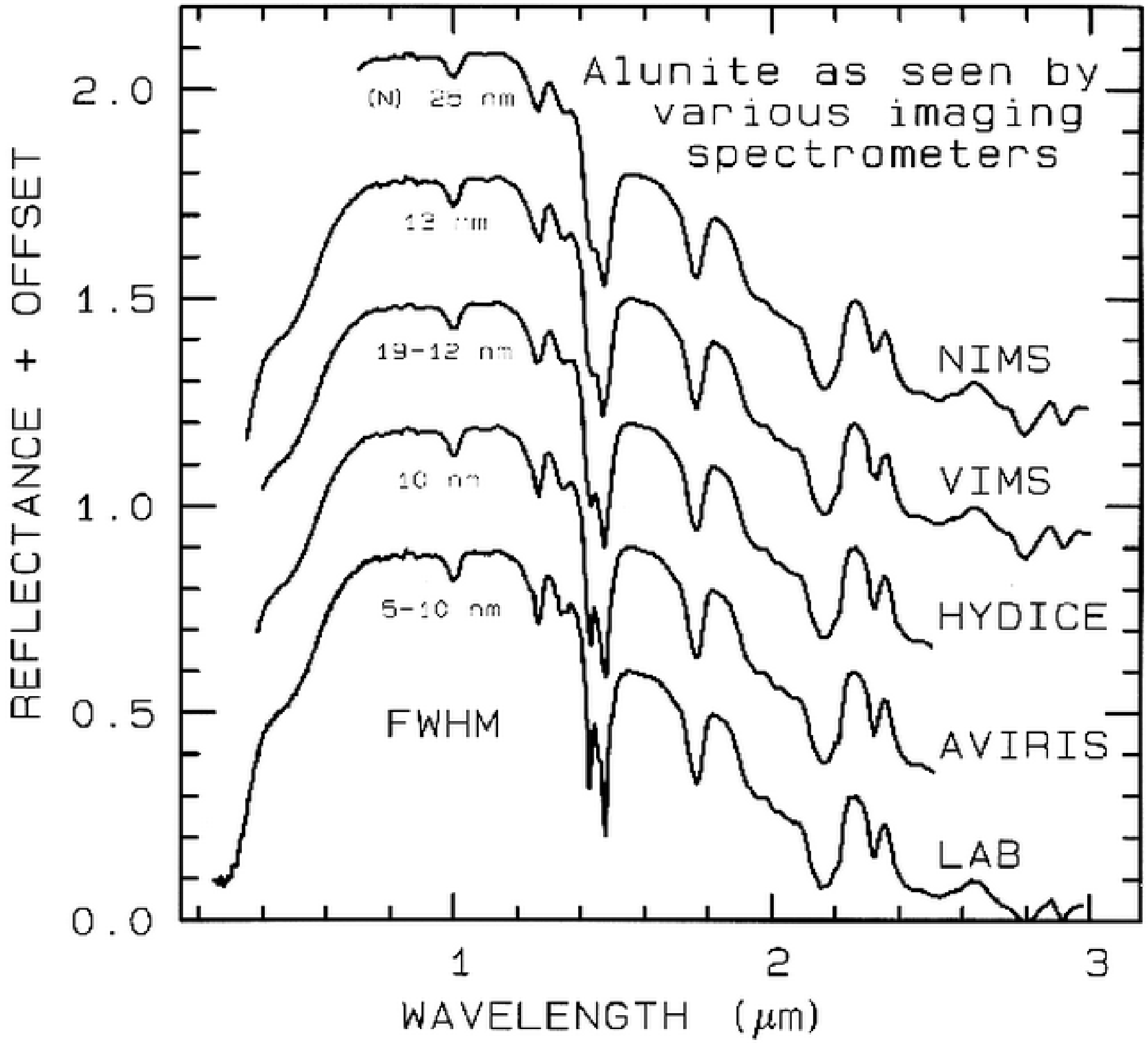


Figure 1b. Spectra of the mineral alunite is shown as measured in the laboratory and for some imaging spectrometers, the NIMS and VIMS systems measure to 5 µm.

Each spectrum is offset upward 0.3 units from the one below it for clarity.

1.4 Imaging Spectroscopy.

- **Today, spectrometers are in use in the laboratory, in the field, in aircraft (looking both down at the Earth, and up into space), and on satellites.**

- Reflectance and emittance spectroscopy of natural surfaces are sensitive to specific chemical bonds in materials, whether solid, liquid or gas. Spectroscopy has the advantage of being sensitive to both crystalline and amorphous materials, unlike some diagnostic methods, like X-ray diffraction. **Spectroscopy's other main advantage is that it can be used up close (e.g. in the laboratory) to far away (e.g. to look down on the Earth, or up at other planets).**

- **Spectroscopy's historical disadvantage is that it is too sensitive to small changes in the chemistry and/or structure of a material**. The variations in material composition often causes shifts in the position and shape of absorption bands in the spectrum. Thus, with the vast variety of chemistry typically encountered in the real world, spectral signatures can be quite complex and sometimes unintelligible.

- However, that is now changing with increased knowledge of the natural variation in spectral features and the causes of the shifts. As a result**, the previous disadvantage is turning into a huge advantage, allowing us to probe ever more detail about the chemistry of our natural environment.**

- **With the advances in computer and detector technology, the new field of imaging spectroscopy is developing**

- **Imaging spectroscopy is a new technique for obtaining a spectrum in each position of a large array of spatial positions so that any one spectral wavelength can be used to make a recognizable image**. The image might be of a rock in the laboratory, a field study site from an aircraft, or a whole planet from a spacecraft or Earth-based telescope.

- By analyzing the spectral features, and thus specific chemical bonds in materials, one can map where those bonds occur, and thus map materials. **Such mapping is best done, in this author's opinion, by spectral feature analysis.**

- **Imaging spectroscopy has many names in the remote sensing community, including imaging spectrometry, hyperspectral, and ultraspectral imaging. Spectroscopy is the study of electromagnetic radiation.**

1.5 Atmospheric Transmittance: Windows for Remote Sensing.

- Any effort to measure the spectral properties of a material through a planetary atmosphere, must consider where the atmosphere absorbs.

- The ultraviolet is due to scattering and strong **ozone absorption at wavelengths short of 0.35 µm.** Ozone also displays an absorption at 9.6 µm. Oxygen absorbs at 0.76 µm in a narrow feature.

- CO_2 absorbs at 2.01, 2.06, and a weak doublet near 1.6 µm. Water causes most of the rest of the absorption throughout the spectrum and hides additional (weaker) absorptions from other gases.

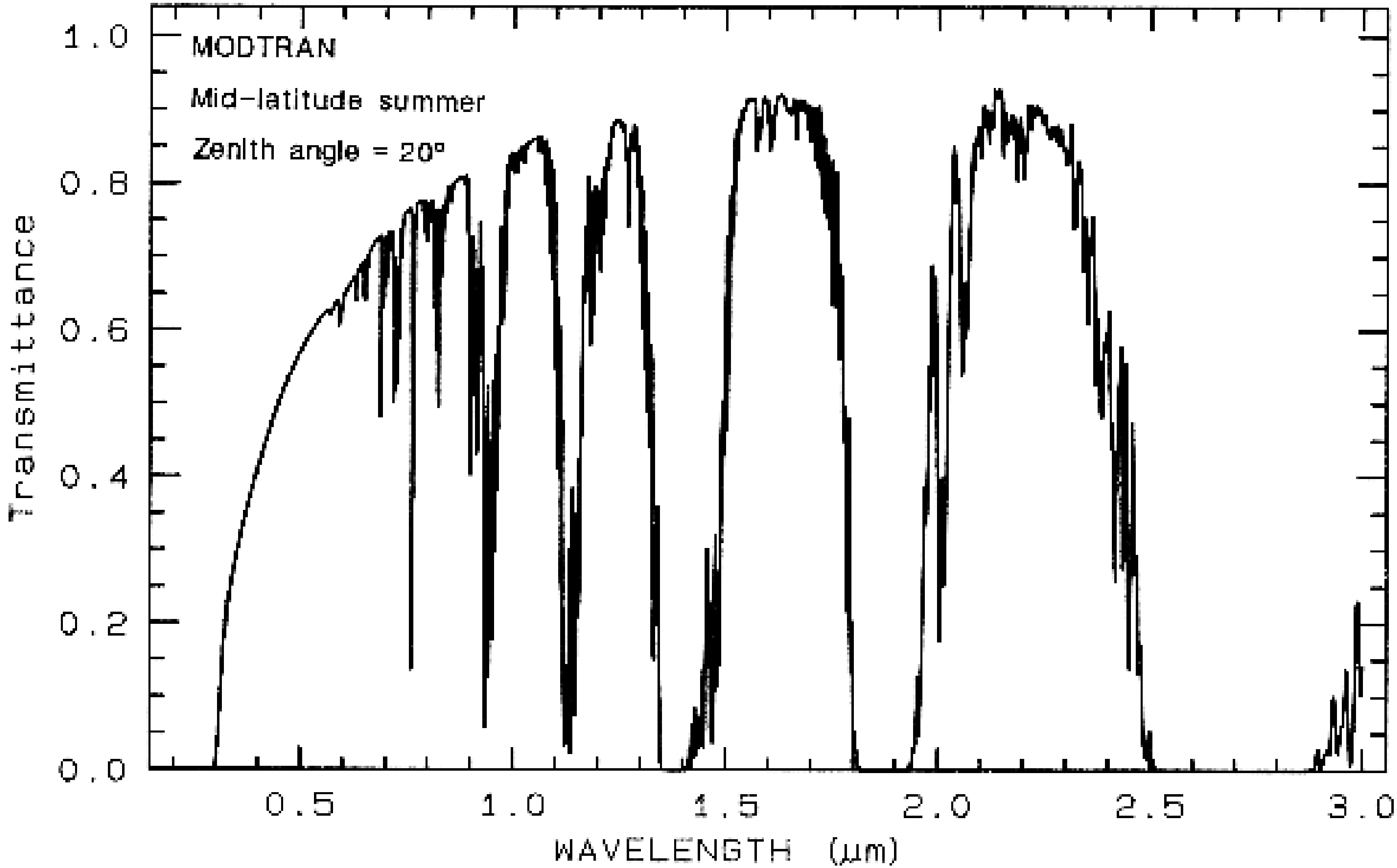
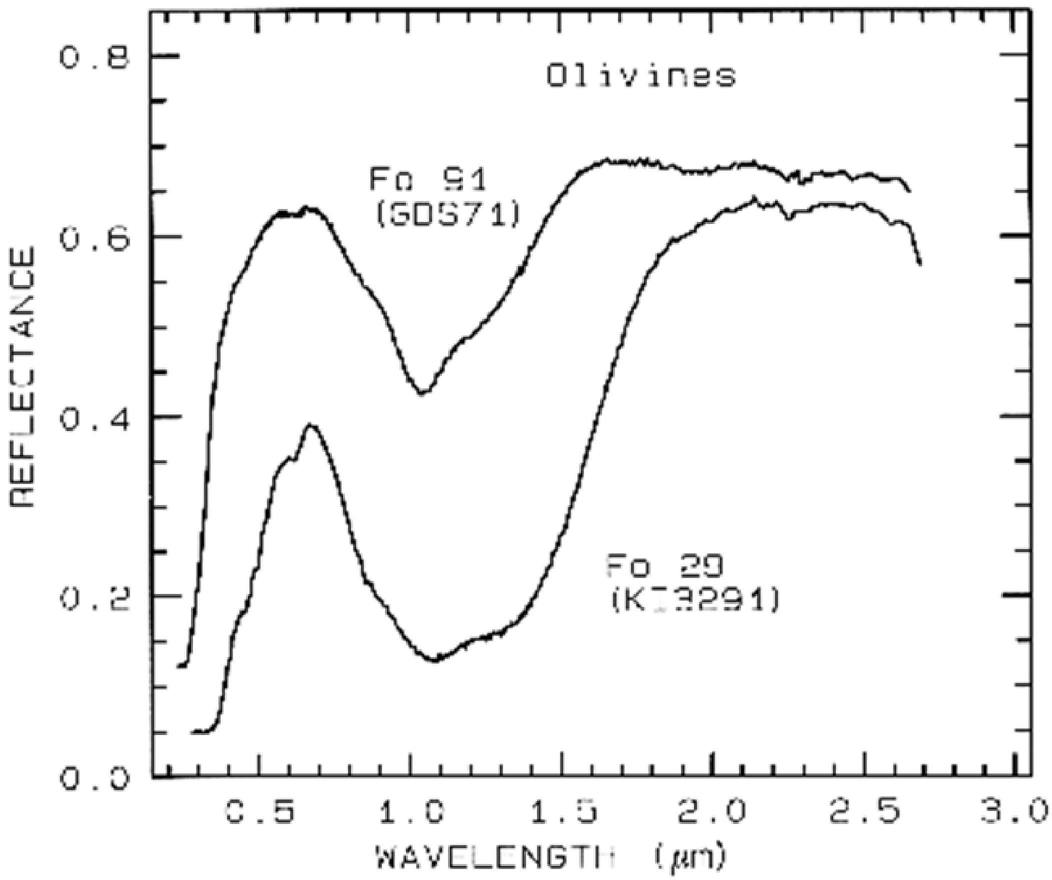


Figure 3a. Modeled atmospheric transmittance, visible to near-infrared.

Most of the absorptions are due to water. Oxygen occurs at 0.76 µm, carbon dioxide at 2.0 and 2.06 µm. See text.

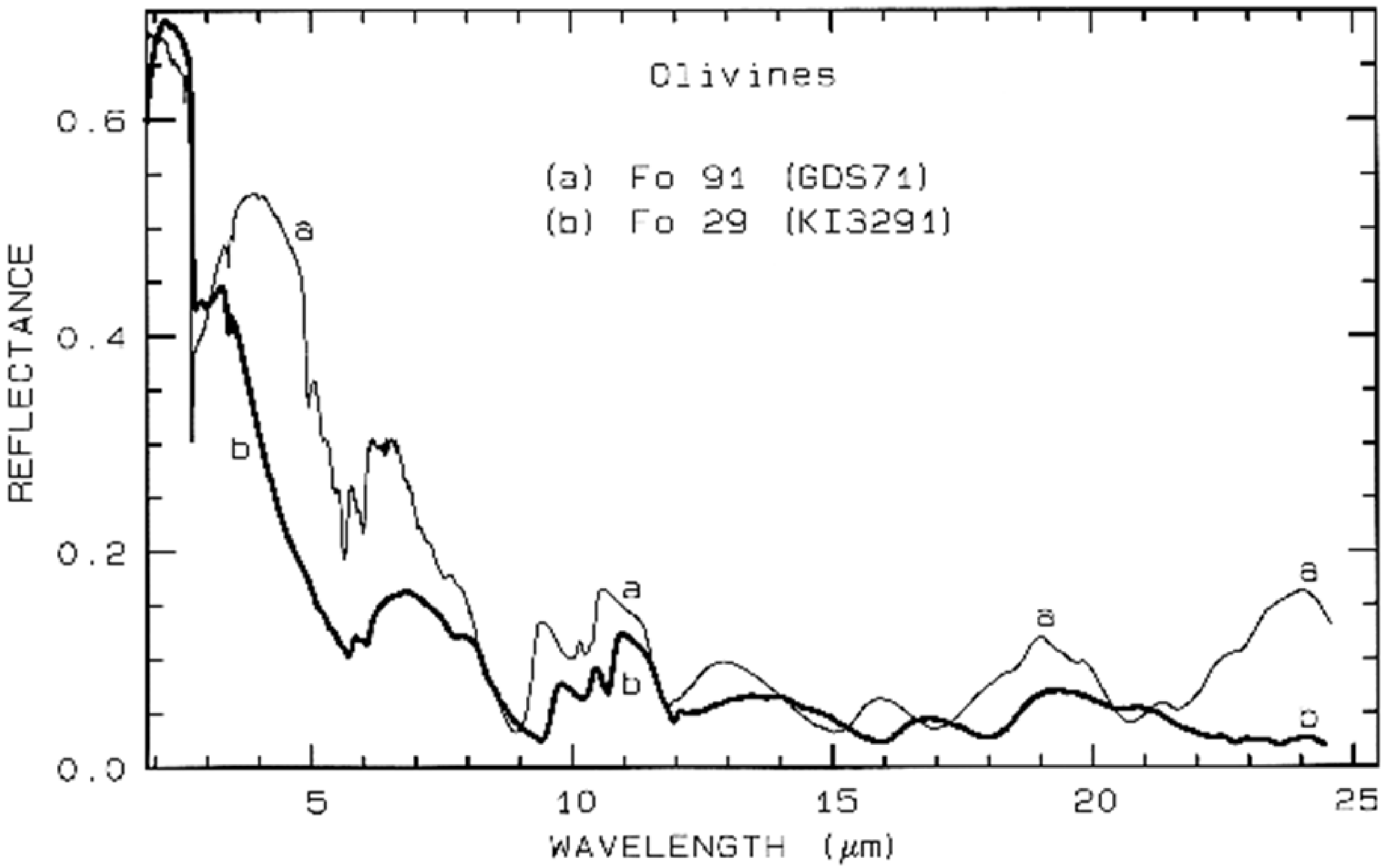


Reflectance spectra of **two olivines** showing the change in band position and shape with composition.

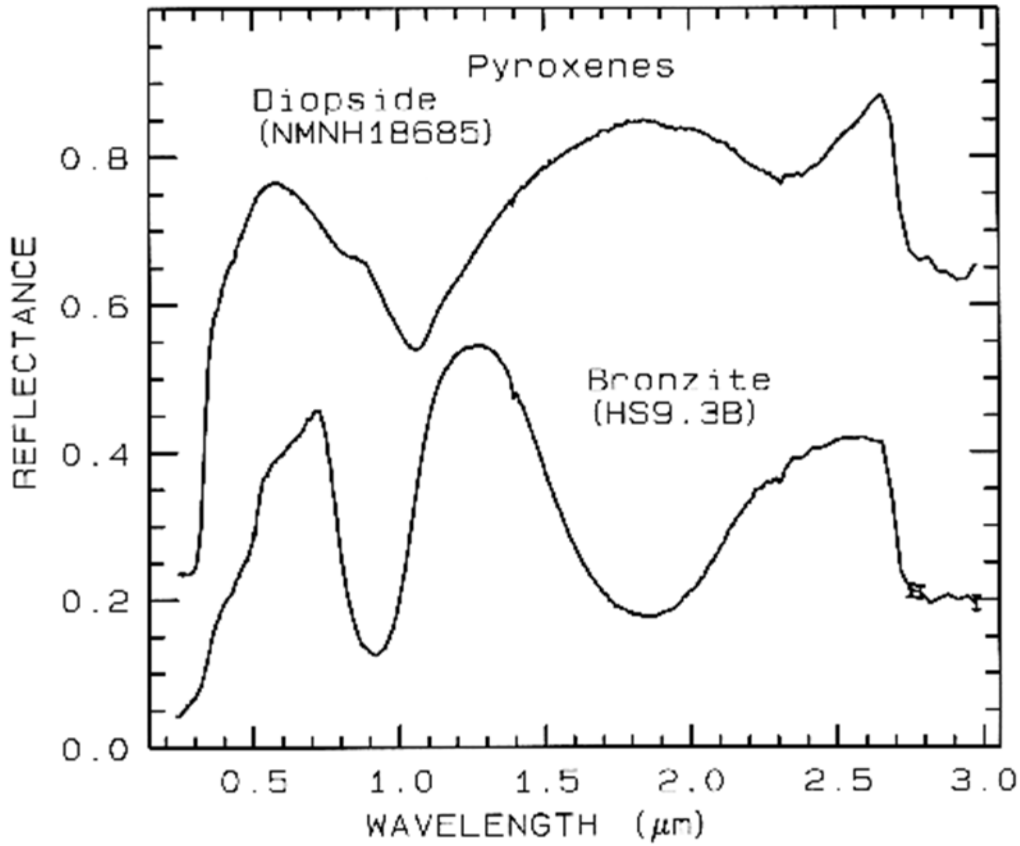
The 1-µm absorption band is due to a crystal field absorption of Fe^{2+}. "Fo" stands for forsterite (Mg_2SiO_4) in the forsterite-fayalite ($Fe_2^{2+}SiO_4$) olivine solid solution series.

The Fo 29 sample (KI3291) has an FeO content of 53.65%, while the Fo 91 sample (GDS 71) has an FeO content of 7.93%. The mean grain size is 30 and 25 µm respectively.

The 1-µm band position varies from about 1.08 µm at Fo 10 to 1.05 µm at Fo 90



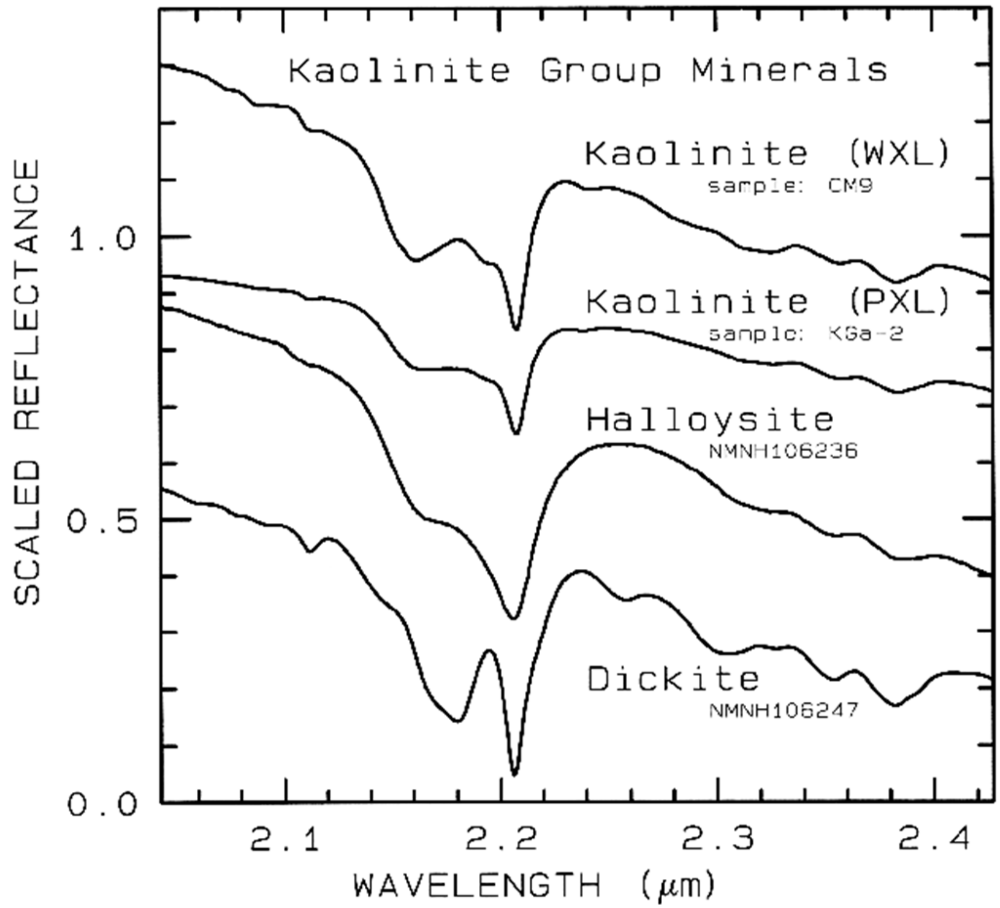
For Mid-infrared wavelengths. Note the shifts in the spectral features due to the change in composition.



Reflectance spectra of two pyroxenes showing the change in **Fe^{2+}** -absorption band position and shape with composition.

Diopside, sample NMNH18685, is $CaMgSi_2O_6$, but some Fe^{2+} substitutes for Mg. Bronzite, sample HS9.3B, is $(Mg,Fe)SiO_3$ with mostly Mg.

The 1-µm versus the 2-µm band position of a pyroxene describes the pyroxene composition.

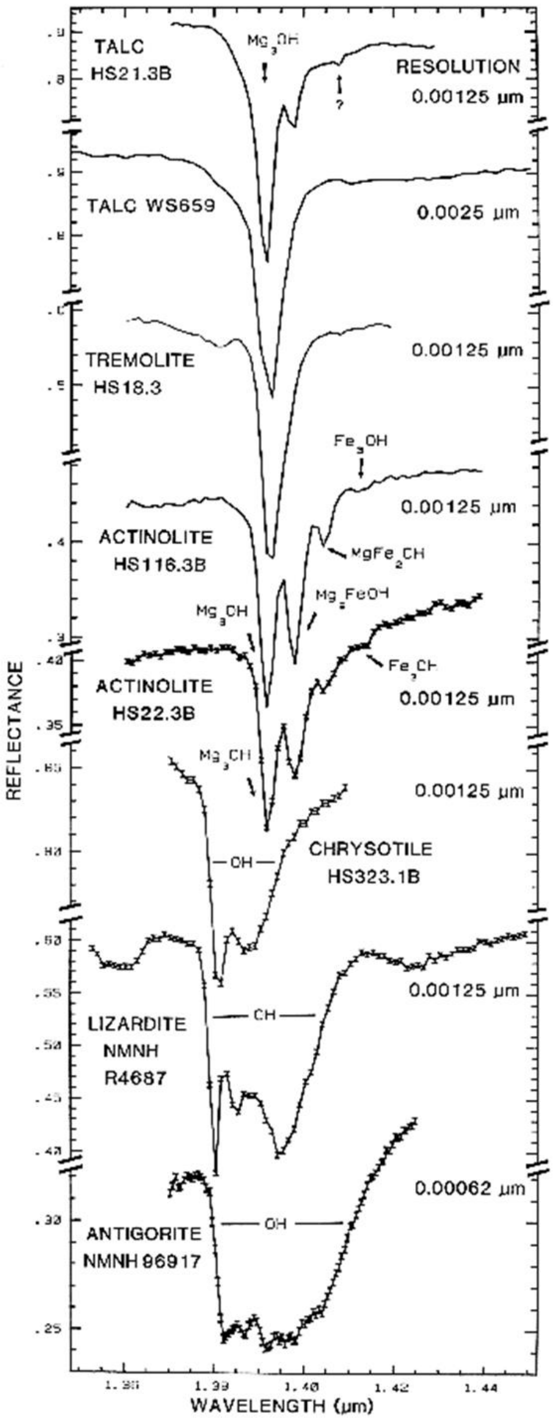


Subtle spectral differences in the kaolinite group minerals near 2.2-µm.

Kaolinite CM9 is well crystallized (WXL) while KGa-2 is poorly crystallized (PXL).

Spectral bandwidth is 1.9 nm and sampling is 0.95 nm. Each spectrum was scaled to 0.7 at 2.1 µm then offset up or down so that the curves to not overlap.

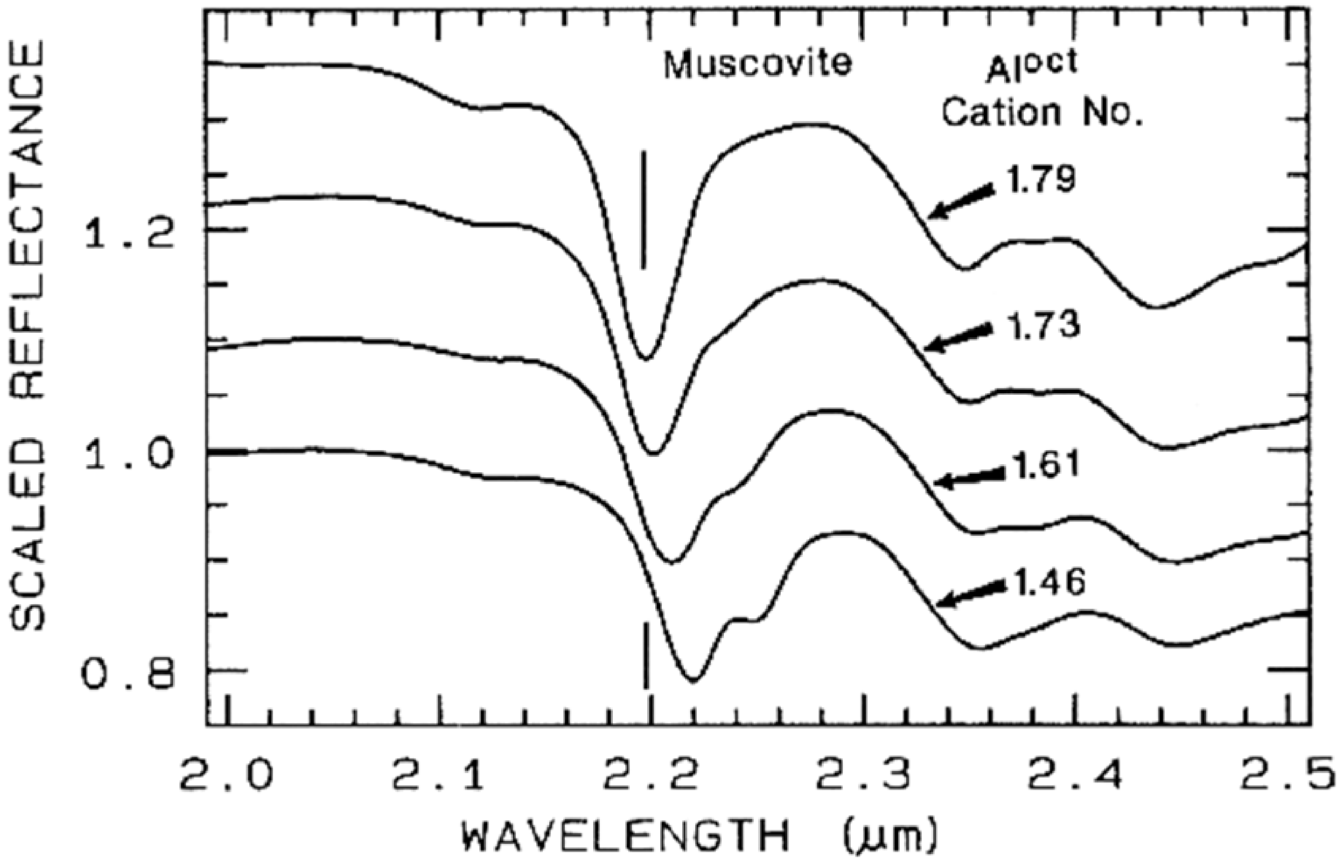
Original reflectances were between 0.5 and 0.8.



High spectral resolution reflectance spectra of the first overtone of OH in talc, tremolite, actinolite, crysotile, lizardite, and antigorite.

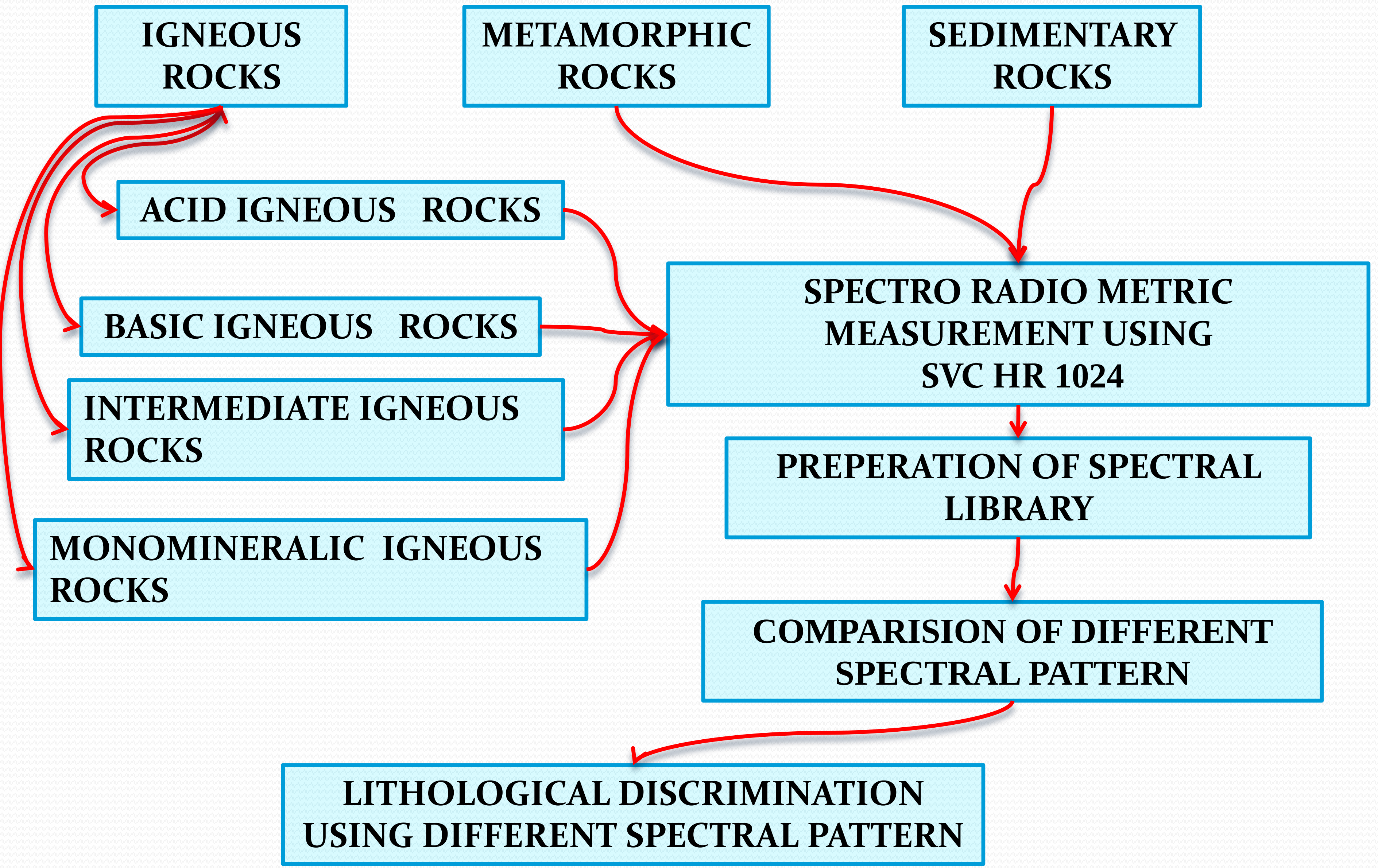
The three sharp absorption bands in talc, tremolite and actinolite are caused by Mg and Fe ions associated with the hydroxyls, causing small band shifts.

The Fe:Fe+Mg ratio can be estimated. In chrysotile, lizardite and antigorite, the absorptions change with small structural differences even though the composition is constant



Reflectance spectra of muscovite showing band shifts due to changing aluminum composition.

METHODOLOGY



SVC HR-1024

- SPECTRAL RANGE 350-2500nm
- INTERNAL MEMORY 500 scans
- FOV
- WEIGHT 3.3Kg
- BATTERY TYPE 7.4 V Lithium ion
- BATTERY LIFE 3 +Hours
- OPERATING
  ENVIRONMENT -10°to +41°


HR 1024
SVC
SVC


HR 1024
SVC
SVC

IGNEOUS ROCKS

ACID IGNEOUS ROCKS

- Granite
- Granodiorite
- Granite porphyry
- Graphic Granite
- Pegmatite

BASIC IGNEOUS ROCKS

- Gabbro
- Norite

INTERMEDIATE IGNEOUS ROCKS

- Diorite porphyry
- Dolerite porphyry
- Trachyte

MONOMINERALIC IGNEOUS ROCKS

- Anorthoscite
- Dunite
- pyroxinite

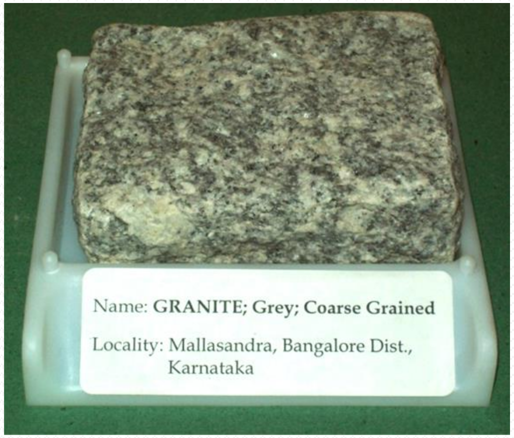
METAMORPHIC ROCKS

- Augen Gneiss
- Biotite Schist
- Chlorite Schist
- Grey Slate
- Hornblende-schist
- Dolomite-marble
- Mica-schist
- Quartzite

SPECTRAL LAB ANALYSIS

IGNEOUS ROCKS

GRANITE (Coarse)



Physical properties:

Color :Leucocratic

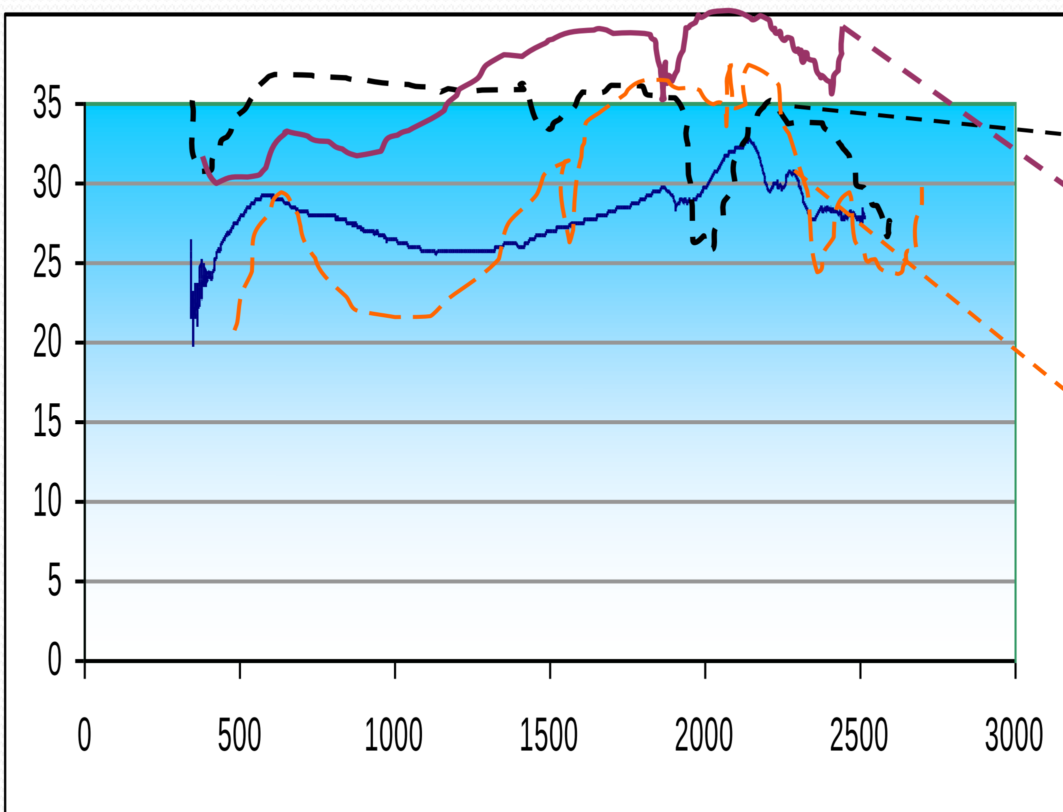
Sp.gravity:Medium

Texture:equigranular

Origin: plutonic

Mineral composition:

Quartz,Feldspar,Mica



Spectral characteristics:

Quartz:

0.5x10-9(Refl.Max)
2.43x10-9(Absorb.Max)

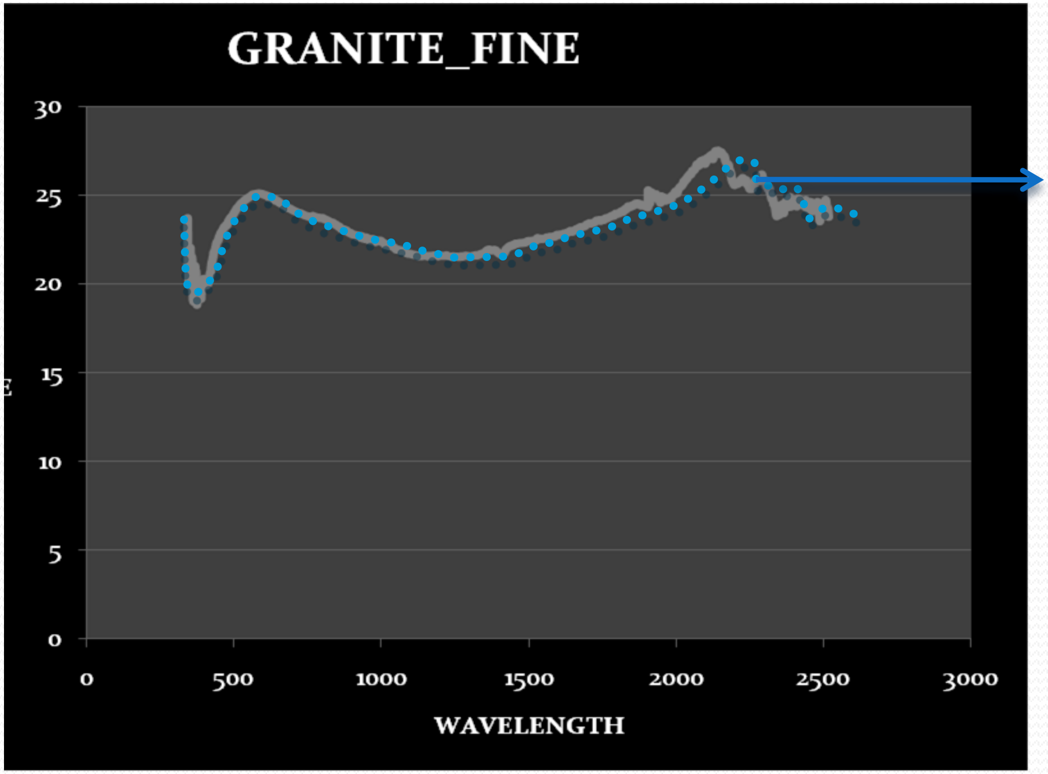
Feldspar:

2.3x10-9(Refl.Max)
0.4x10-9(Absorb.Max)

Mica:

1.9x10-9(Refl.Max)
0.4x10-9(Absorb.Max)

GRANITE (fine)



GRANITE_COARSE

Physical properties:

Color :Leucocratic

Sp.gravity:Medium

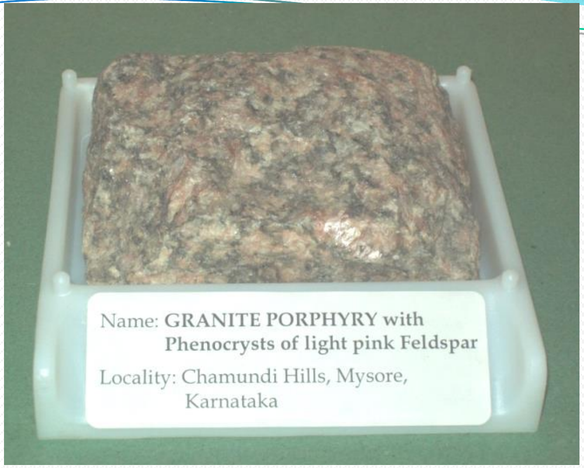
Texture :Equigranular

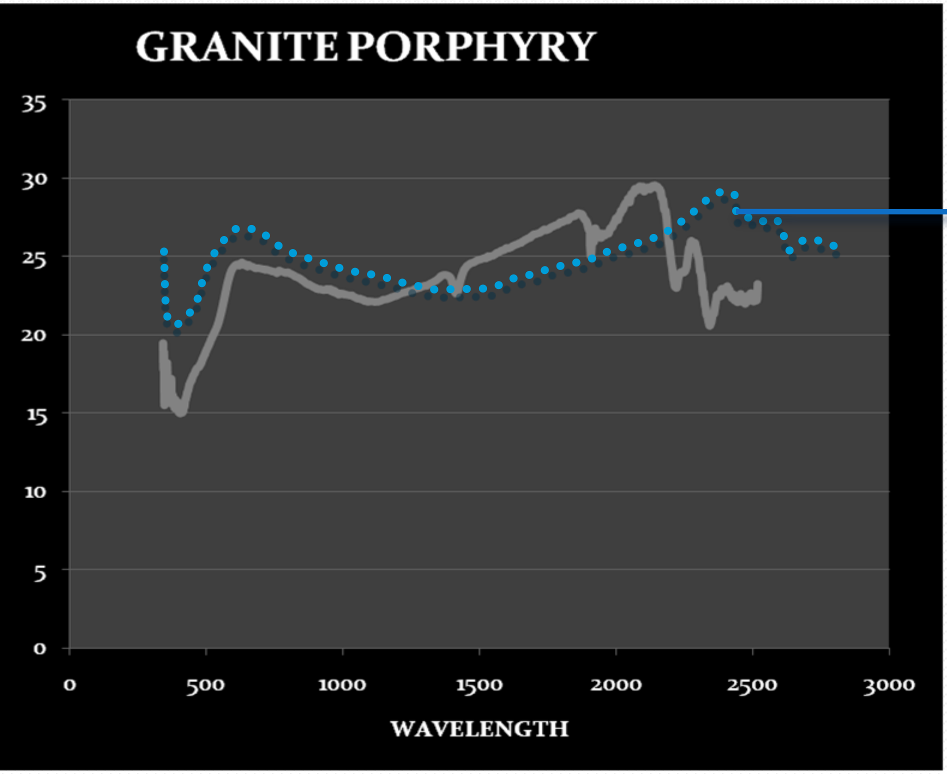
Origin :Plutonic

Mineral composition:

Quartz,Feldspar,Mica

GRANITE PORPHYRY





GRANITE_COARSE

MINERAL COMPOSITION:

orthoclase

GRANO DIORITE

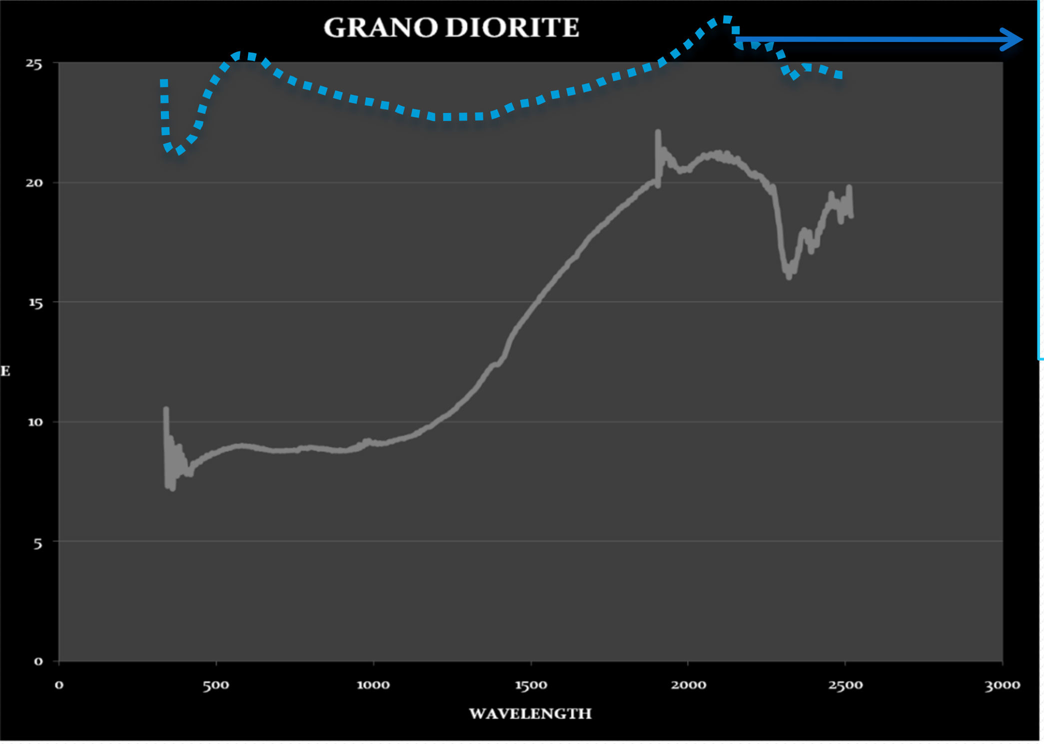
Physical properties:

Color :Mesocratic

Sp.gravity:High

Texture :Equigranular

Origin :Plutonic

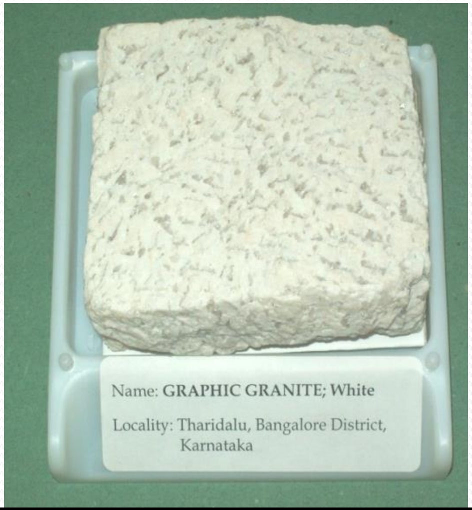


GRANITE_COARSE

Mineral composition:

Quartz, Plagioclase(albite&oligoclase)

GRAPHIC GRANITE



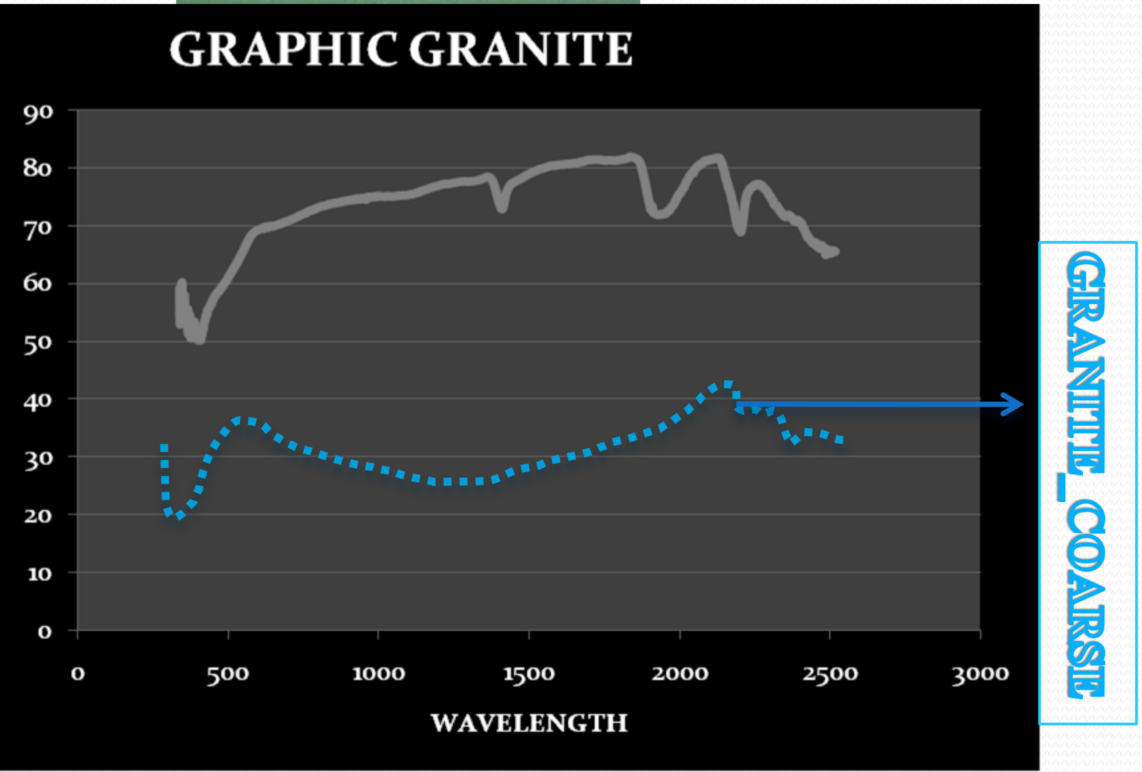
Physical properties:

Color :Mesocratic

Sp.gravity:High

Texture: equigranular

Origin: plutonic



Mineral composition

quartz& Plagioclase.

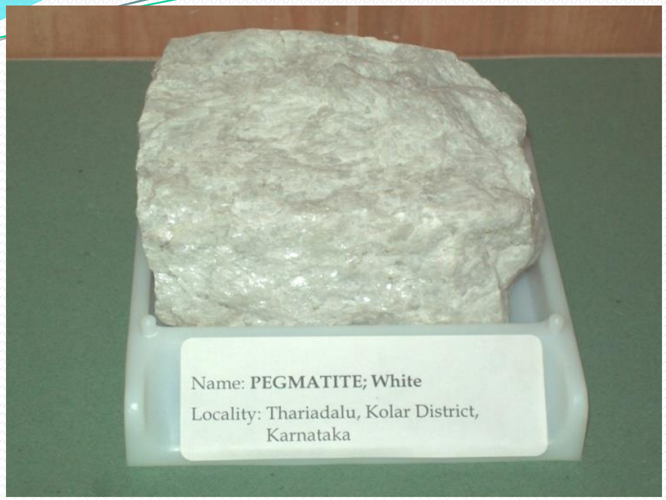
Spectral characteristics:

Plagioclase:

$0.4x10^{-9}$(Refl.Max)

$2.4x10^{-9}$(Absorb.Max)

PEGMATITE



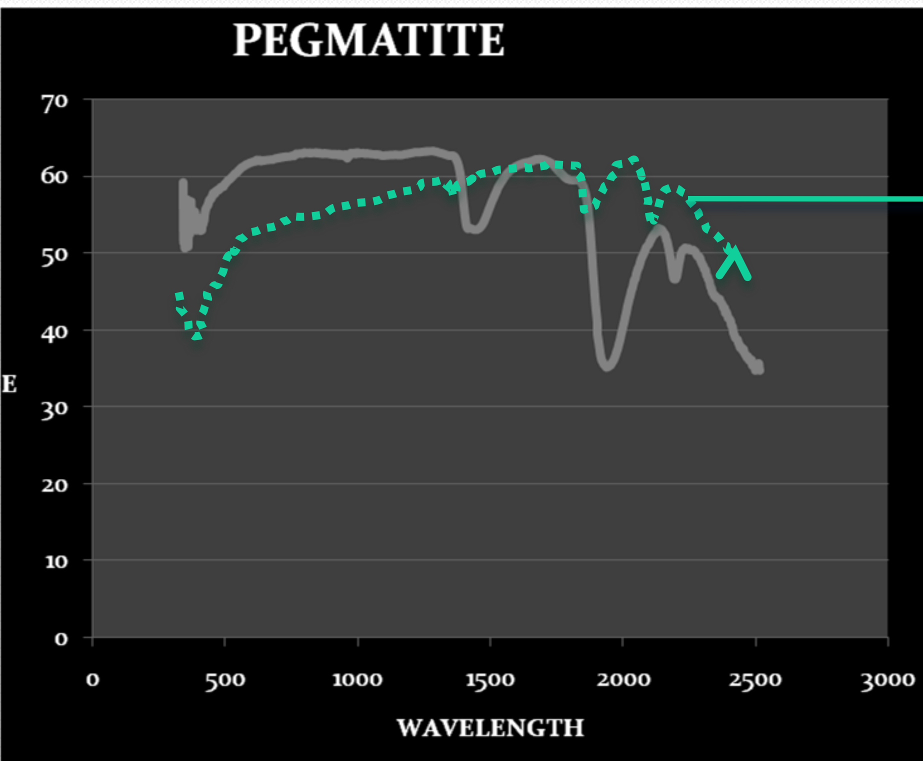
Physical properties:

Color :Mesocratic

Sp.gravity:High

Texture:equigranular

Origin: plutonic



GRAPHIC GRANITE

Mineral composition:

Quartz, Plagioclase(Albite)& Muscovite.

Spectral characters

Quartz:

2.05×10^{-9}(Refl.Max)

2.43×10^{-9}(Absorb.Max)

Plagioclase:

0.4×10^{-9}(Refl.Max)

2.4×10^{-9}(Absorb.Max)

Muscovite

1.9×10^{-9}(Refl.Max)

0.4×10^{-9}(Absorb.Max)

SYENITE

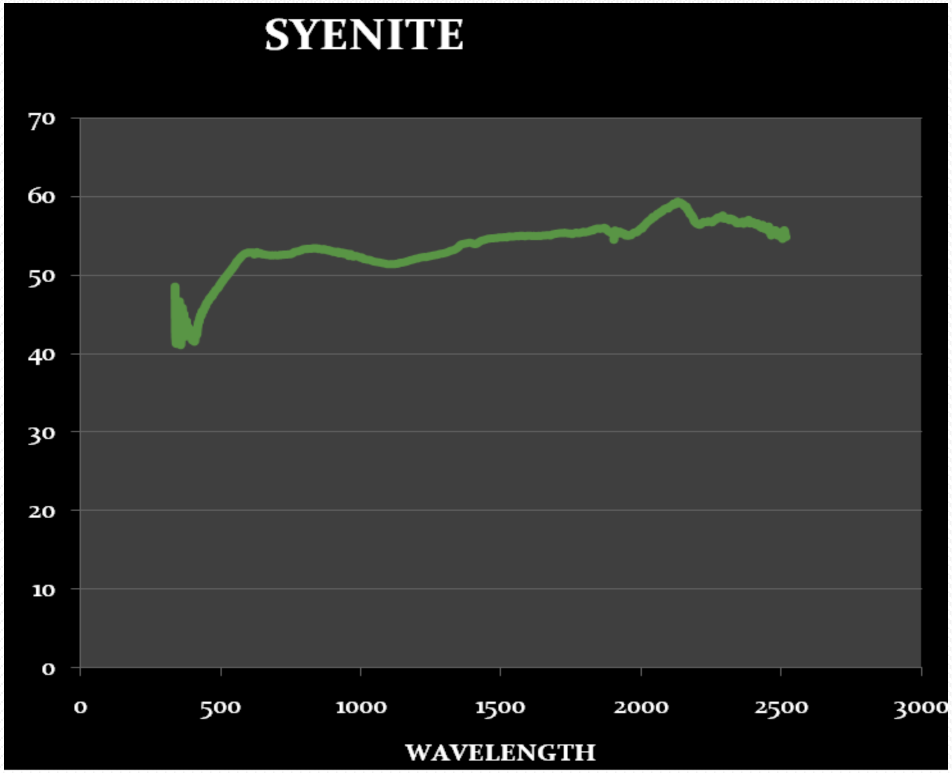
Physical properties:

Color :Mesocratic

Sp.Gravity: Medium

Texture :Equigranular

Origin: Plutonic

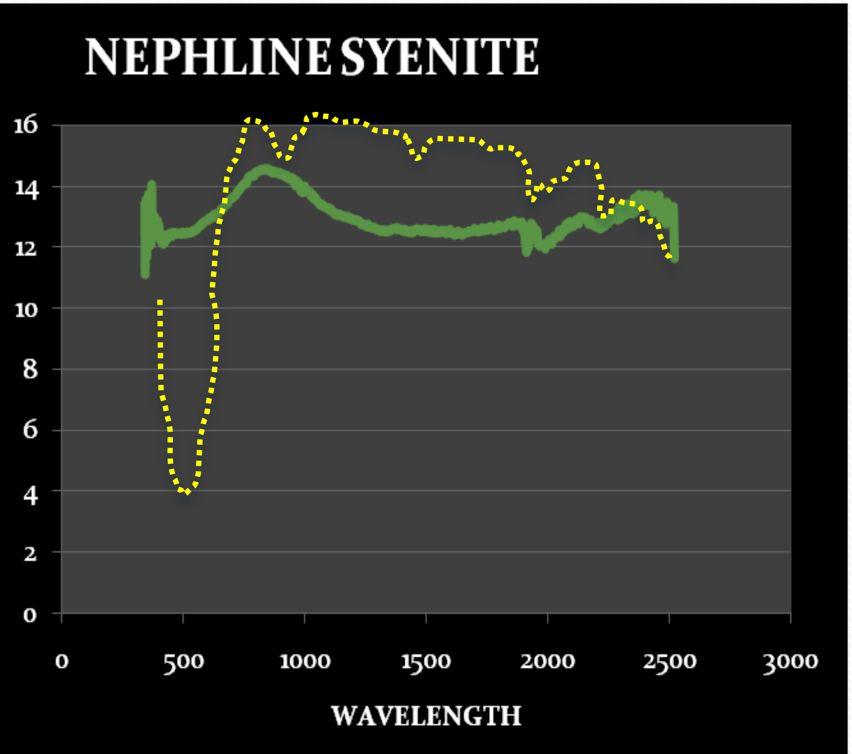


Mineral Composition:

Albite & Orthoclase

(59%of Silica)

NEPHLINE SYENITE



Physical properties:

Color :Mesocratic

Sp.gravity:medium

Texture: Inequigranular

Origin: hypapysal

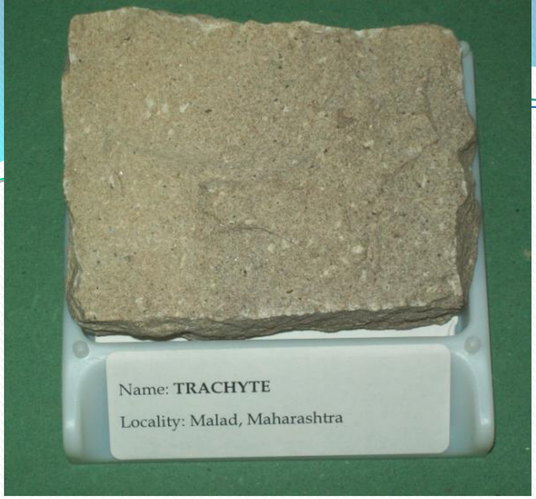
Mineral composition

albite, orthoclase&nephline (54.5% of silica)

Spectral characters

Nephline

0.5×10^{-9}(Refl.Max)
0.9×10^{-9}(Absorb.Max)



Physical properties:

Color :Mesocratic

Sp.gravity:medium

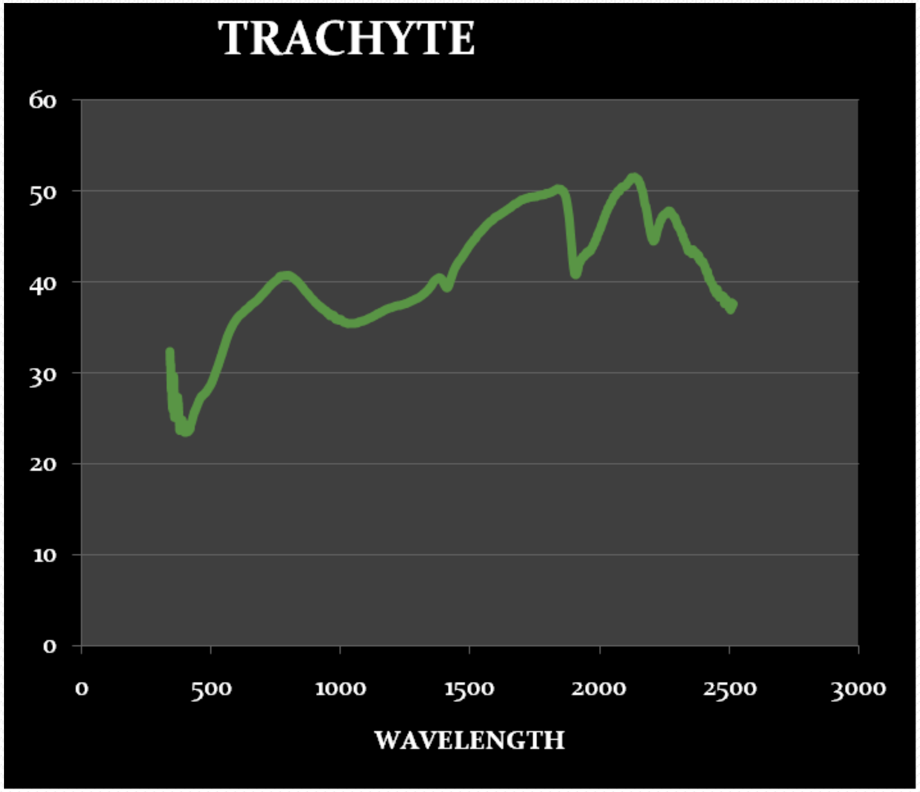
Texture

Crystallity:holocrystalline

Granularity:phaneric

Fabric:inequigranular

Origin: hypapysal



Mineral composition:

albite&sanidine

Spectral characters

albite:

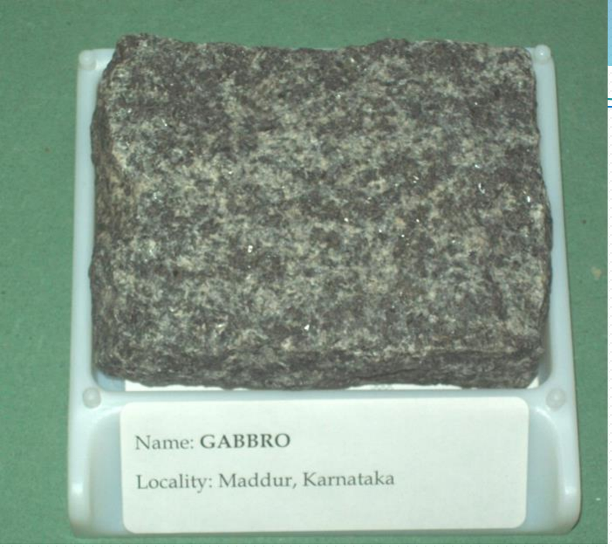
$x10^{-9}$(Refl.Max)

$x10^{-9}$(Absorb.Max)

sanidine:

$x10^{-9}$(Refl.Max)

$x10^{-9}$(Absorb.Max)



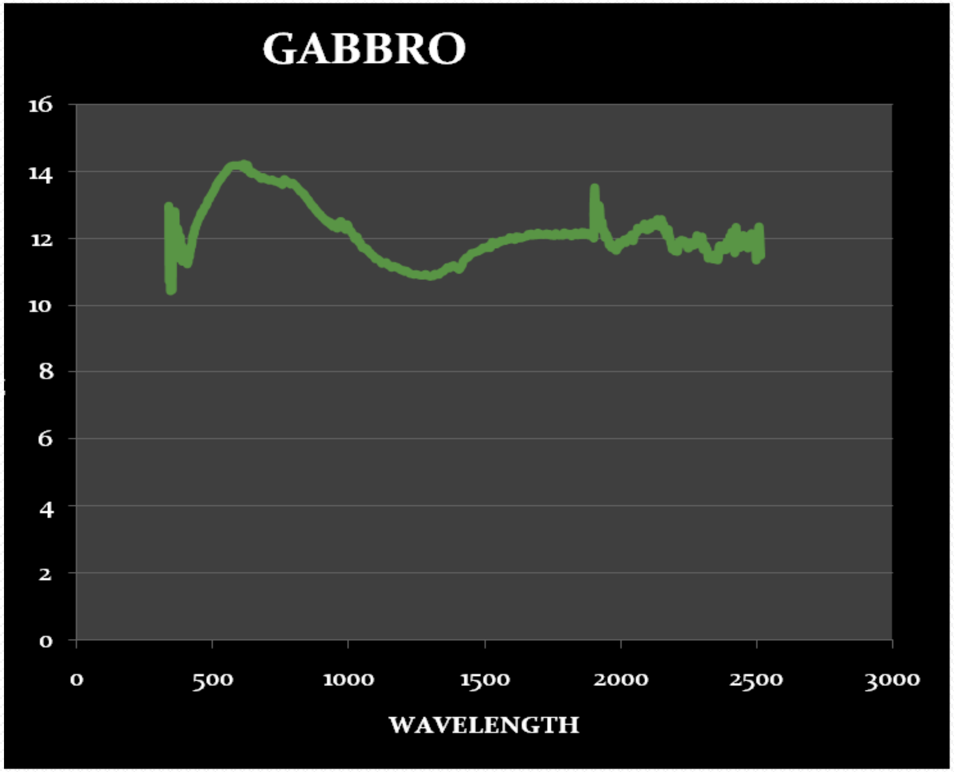
Physical properties:

Color :Mesocratic

Sp.gravity:High

Texture :iquigranular

Origin : plutonic



Mineral composion:

augite&labrodorite.

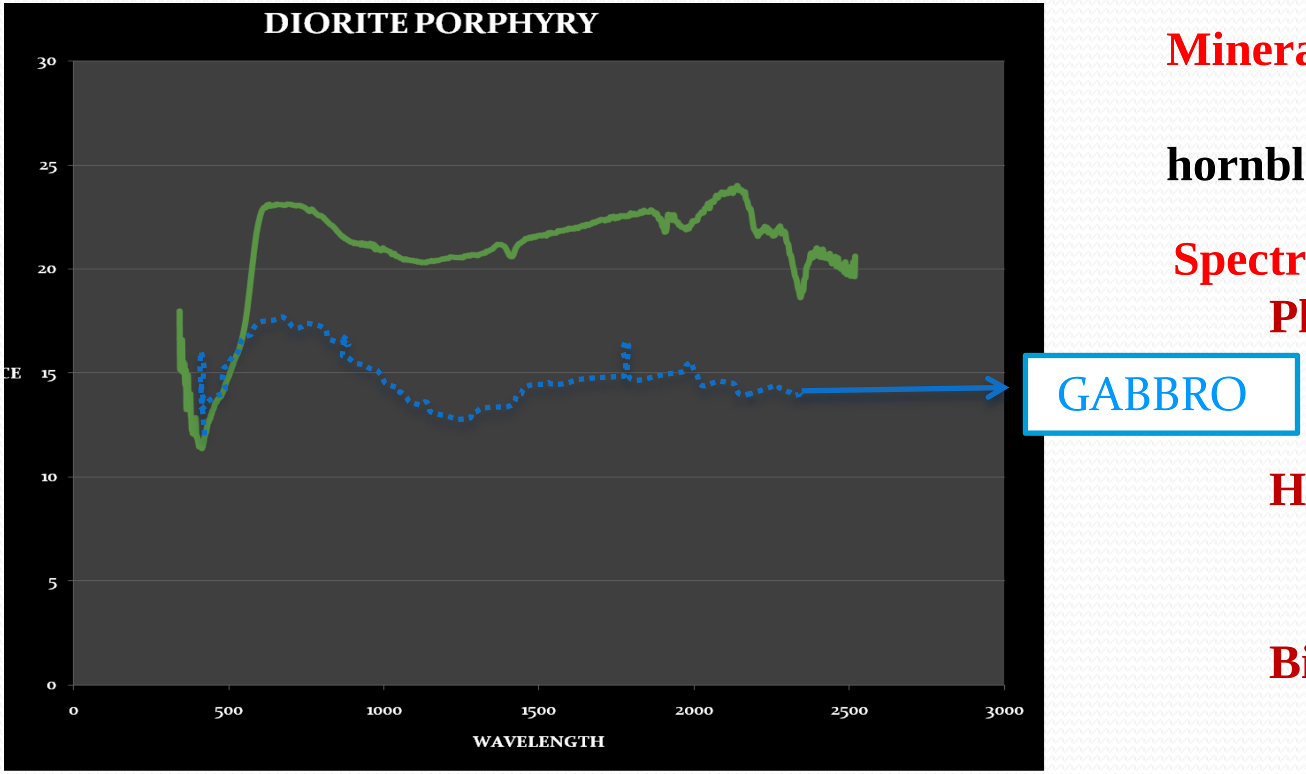
Physical properties:

Color :Mesocratic

Sp.gravity:medium

Texture :inequigranular

Origin : hypapysal



Mineral composition:

Plagioclase(andesine), hornblende,biotite

Spectral characters

Plagioclase:

$2.1x10^{-9}$(Refl.Max)

$0.4x10^{-9}$(Absorb.Max)

Hornblende:

$2.1x10^{-9}$(Refl.Max)

$2.3x10^{-9}$(Absorb.Max)

Biotite

$2.3x10^{-9}$(Refl.Max)

$2.2x10^{-9}$ (Absorb.Max)

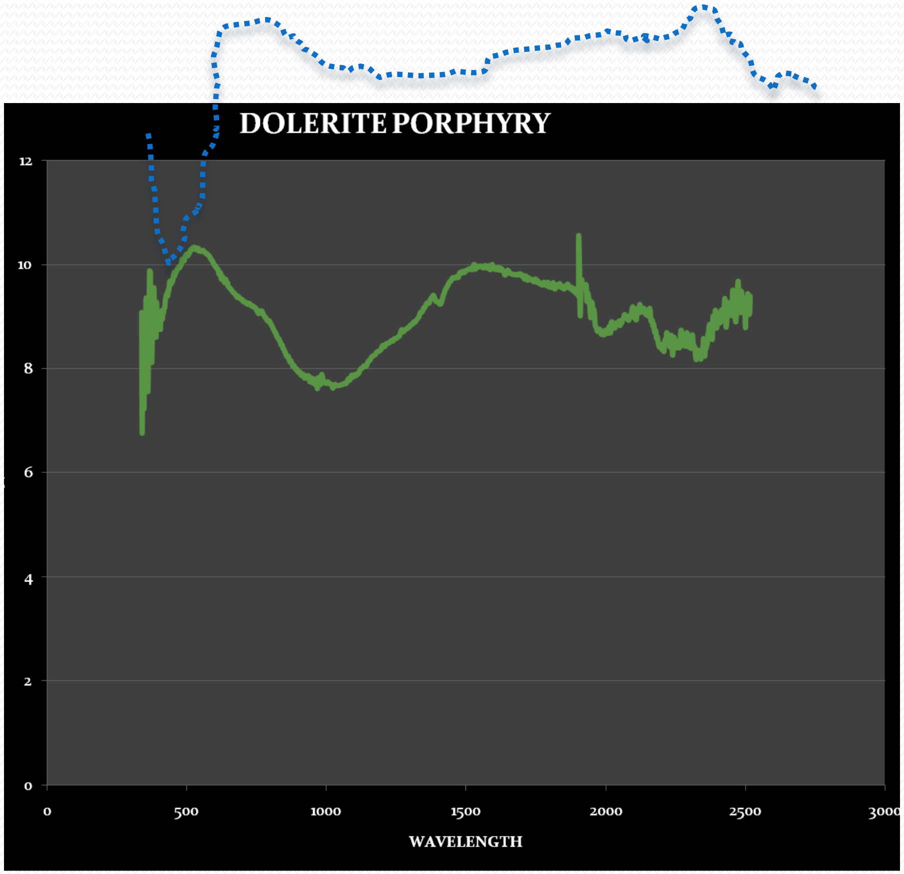
Physical properties:

Color :Melanocratic

Sp.gravity:high

Texture:inequigranular (porphyritic)

Origin: hypapysal



DIORITE PORPHYRY

Mineral composition

Augite&labrodorite

Spectral characters

Augite:

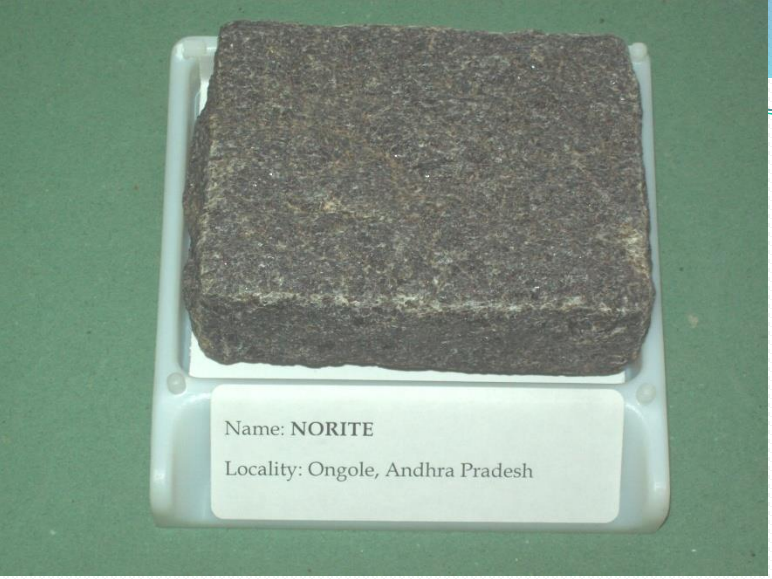
$x10^{-9}$ (Refl.Max)

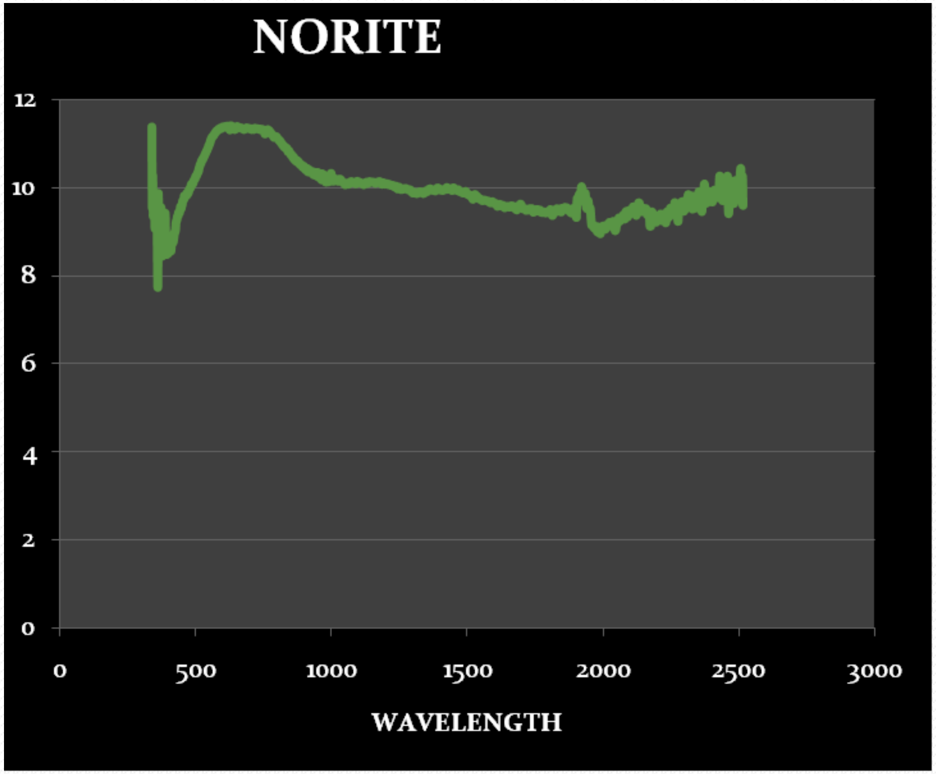
$x10^{-9}$ (Absorb.Max)

Labrodorite:

$x10^{-9}$ (Refl.Max)

$x10^{-9}$ (Absorb.Max)





Mineral composition:

labrodorite,hypersthenes& olivine.

Spectral character:

Labrodorite:

$x10^{-9}$ (Refl.Max)

$x10^{-9}$ (Absorb.Max)

Hypersthene:

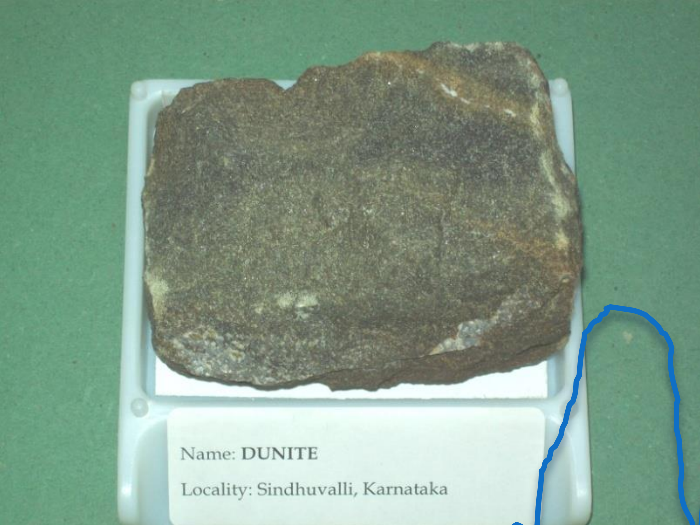
$x10^{-9}$ (Refl.Max)

$x10^{-9}$ (Absorb.Max)

Olivine

$0.4x10^{-9}$ (Refl.Max)

$1.7x10^{-9}$ (Absorb.Max)



Physical properties:

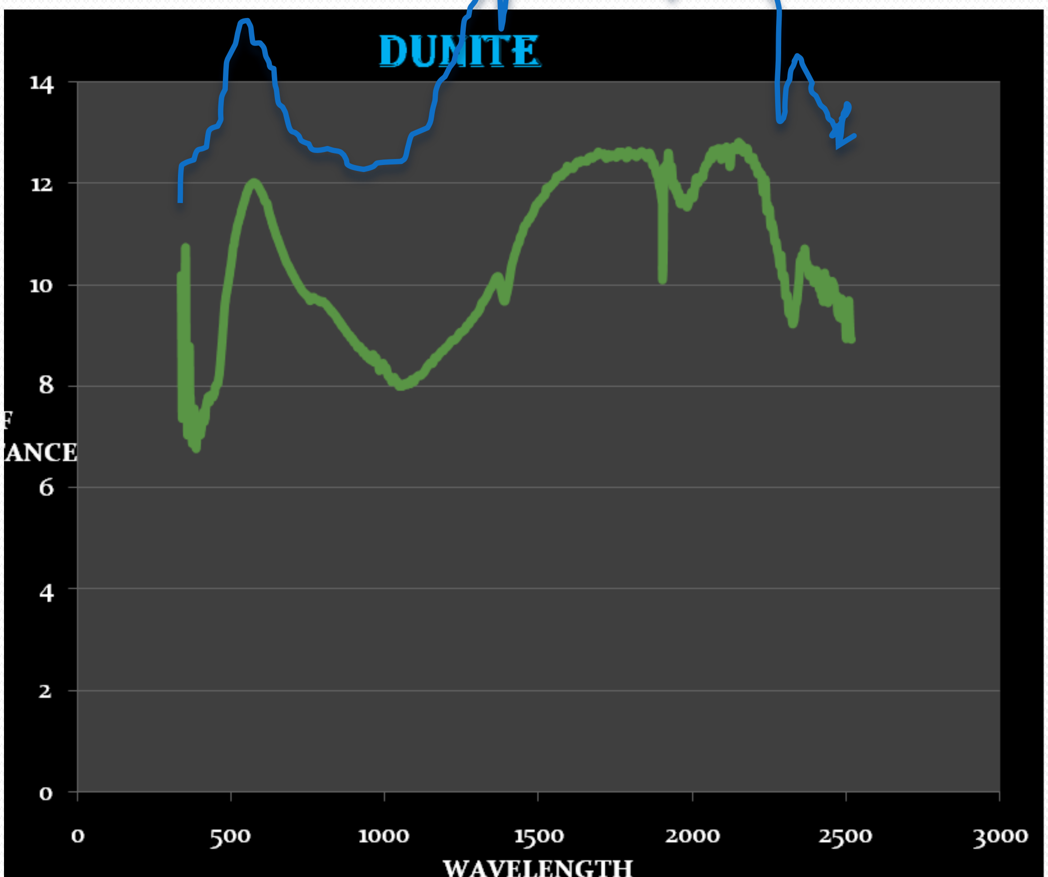
Color :Mesocratic

Sp.gravity:high

Texture :equigranular

Origin: plutonic

OLIVINE



Mineral composition:

olivine.

Spectral reflectance

Olivine

$0.4x10^{-9}$ (Refl.Max)

$1.7x10^{-9}$ (Absorb.Max

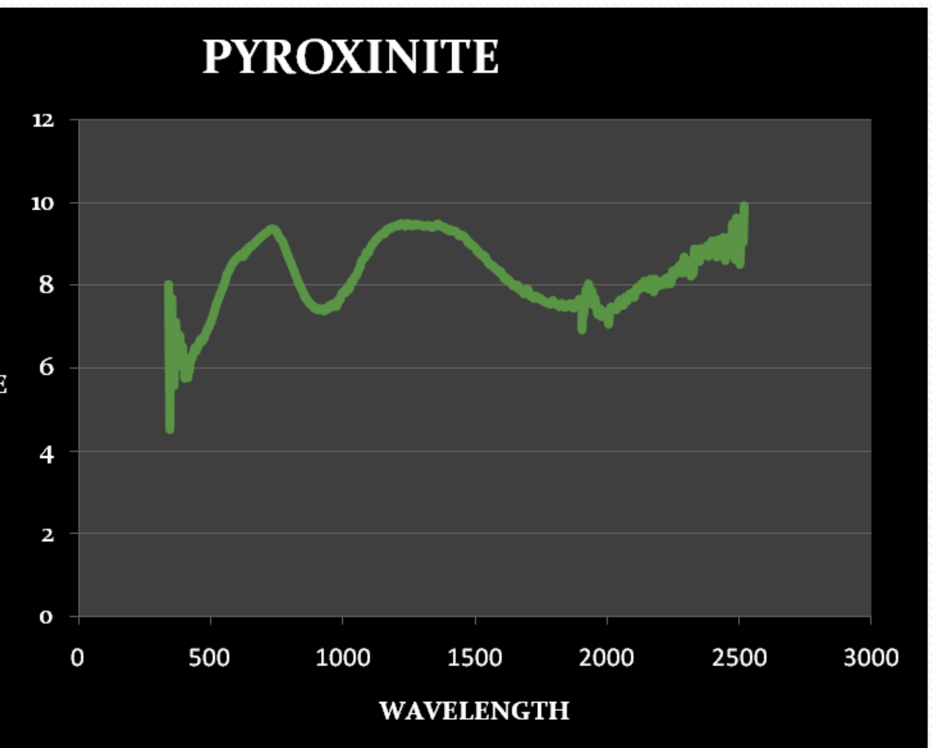
Physical properties:

Color :Mesocratic

Sp.gravity:medium

Texture :inequigranular

Origin: plutonic



Mineral composition:

pyroxene

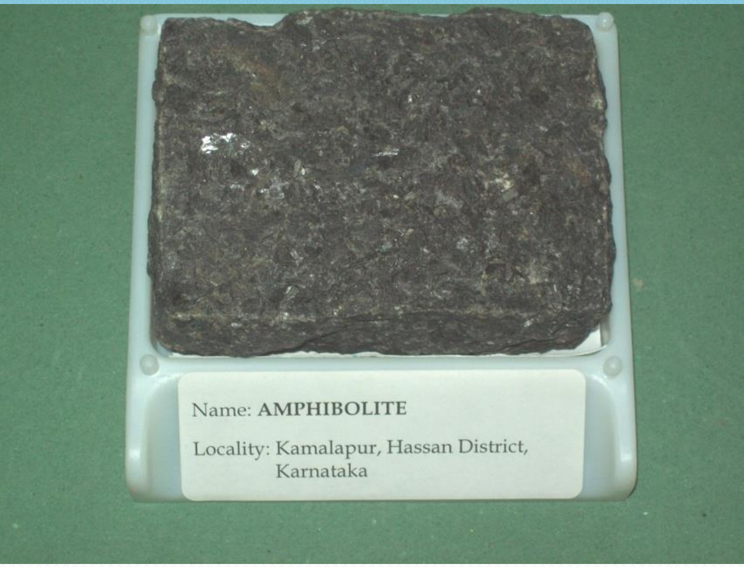
Spectral characters

pyroxine:

$2.5 x 10^{-9}$ (Refl.Max)

$0.34 x 10^{-9}$ (Absorb.Max)

METAMORPHIC ROCKS



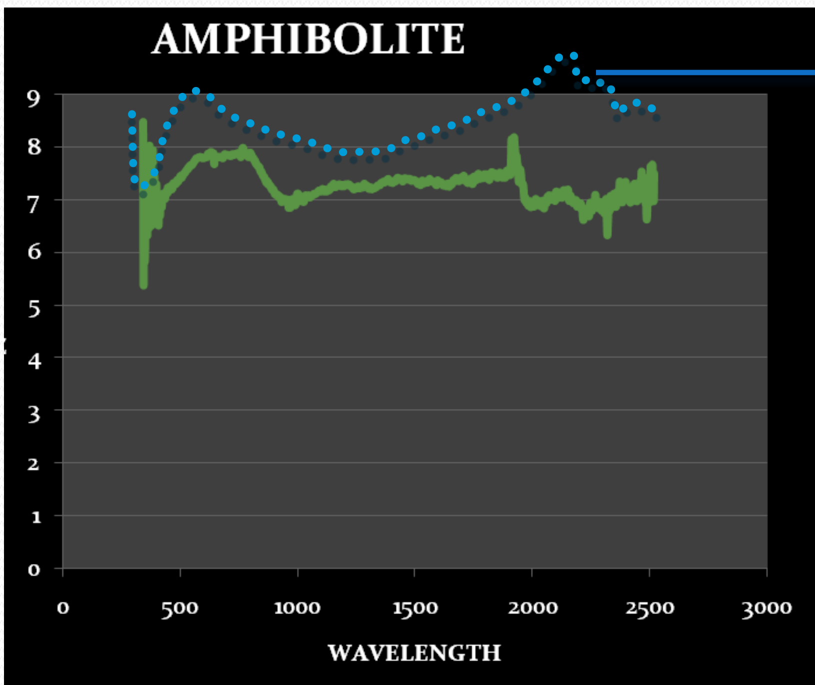
Physical properties:

Color :Dark green

Sp.gravity:medium

Texture :poorly foliated

Origin :high grade regional metamorphism



GRANITE_COARSE

Mineral composition:

amphibole&plagioclase

Spectral characteristics:

Plagioclase:

2.3x10-9(Refl.Max)
0.4x10-9(Absorb.Max)

GNEISS

Physical properties:

Color :grey

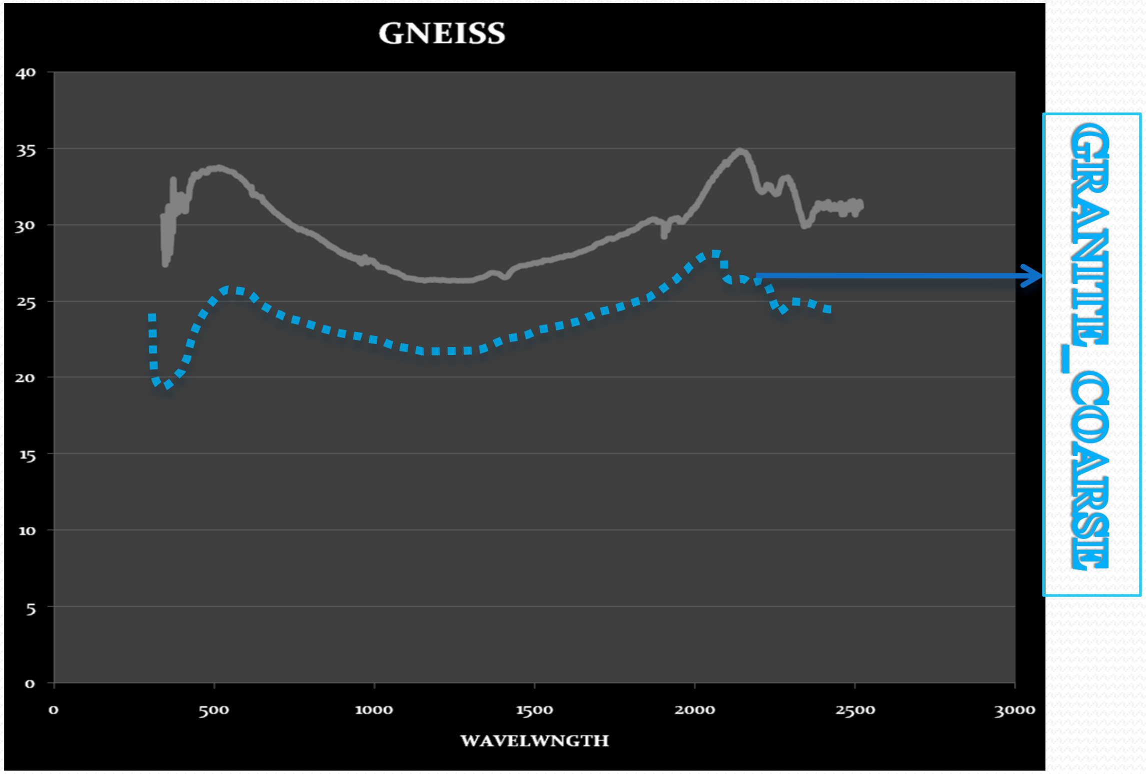
Sp.gravity:medium

Texture :foliated(gneissic)

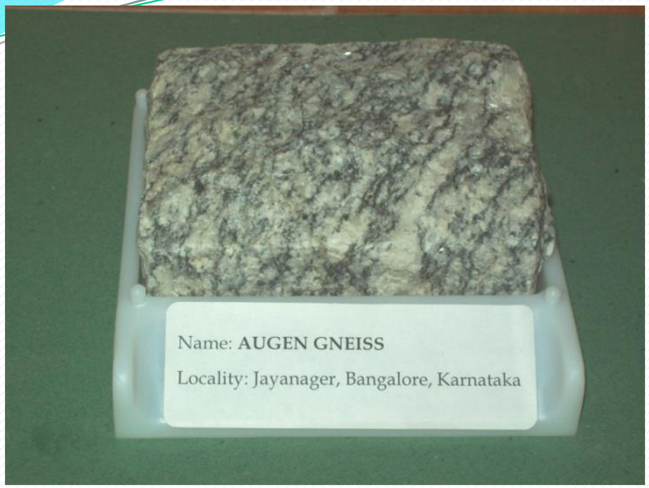
Origin :plutonic

Mineral composition:

Quartz&Feldspar



AUGEN GNEISS



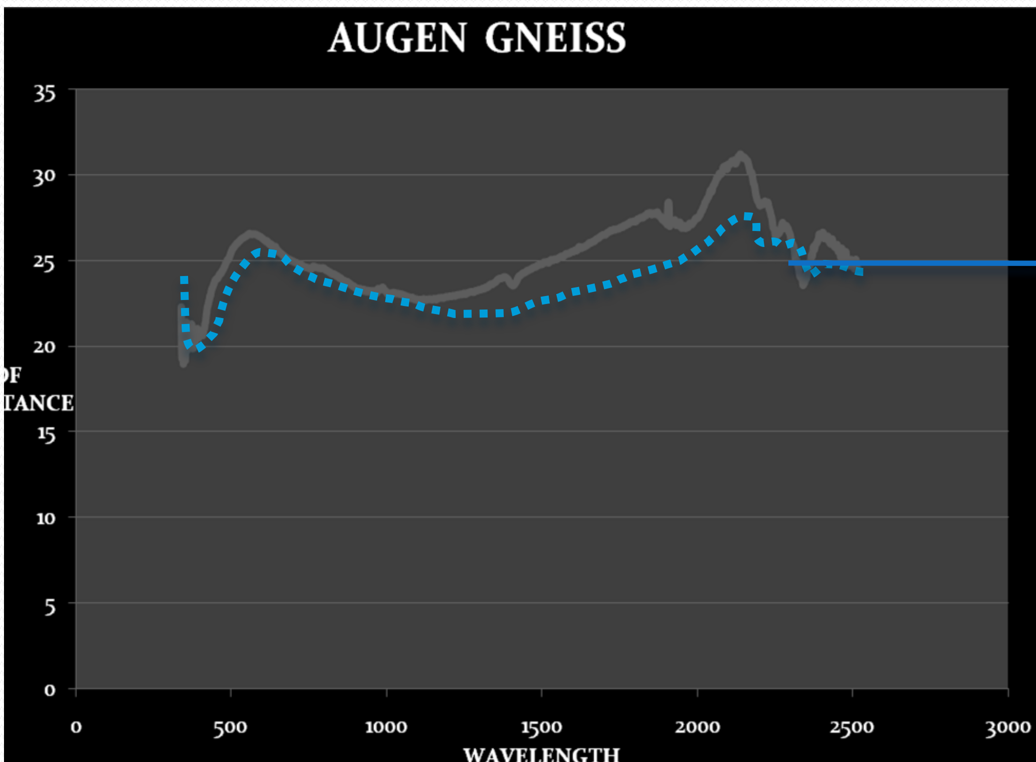
Physical properties:

Color :grey

Sp.gravity:medium

Texture :foliated(gneissic)

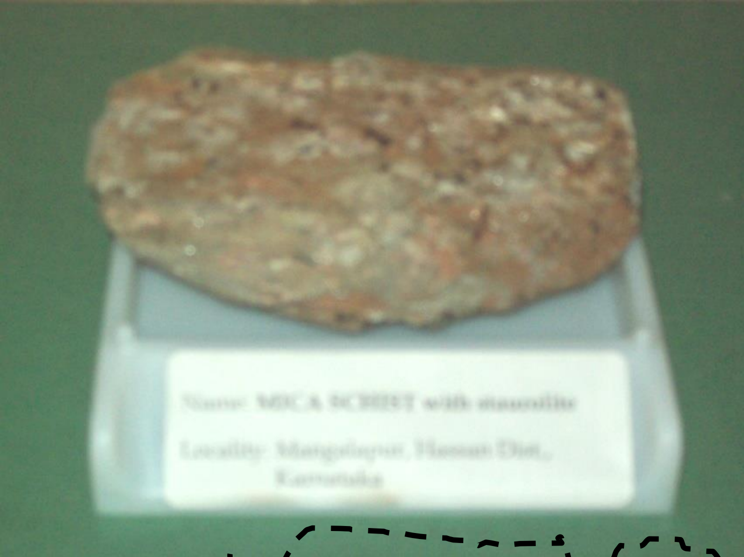
Origin :Dynamic metamorphism



GRANITE_COARSE

Mineral composition:

Quartz ,Feldspar



Physical properties:

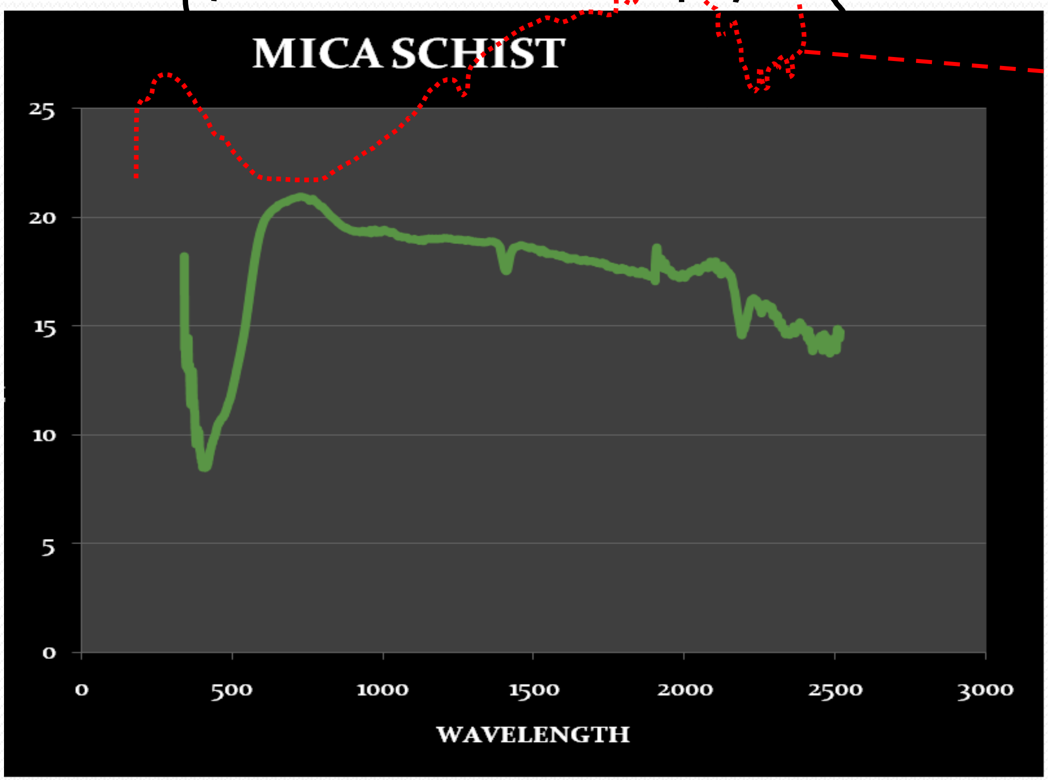
Color :grey

Sp.gravity:medium

Texture :foliated(gneissic)

Origin :low grade metamorphism

Quartz:



Biotite

Mineral composition:

Biotite&quartz

Mapping of Rocks Using Aerial and Satellite Imagery

- **Geological information available on the Ariel Photos will depends primary on the type of terrain whether igneous, metamorphic or sedimentary, the climatic condition and stages of geomorphic cycles.**
- **It is generally believed that sedimentary terrain will yield more information from ariel photographs than Igneous and the area underlain by metamorphic will reveal least information.**
- **Arid area will reveal much more information on geological information.**
- **Different vegetation pattern will give information about the different bed rock in that area.**

- Landform analysis of sedimentary terrain is more easy in images and yield more lithological information than either igneous or metamorphic terrain.
- Flat lying horizontal beds ca be distinguished by banding along topographic contour and by changes in the slope due to presence of soft and hard rock.
- Extrusive and intrusive terrain are picked up by the associated structural features with lithology and surrounding rocks

Sedimentary Rocks

- The Presence of bedding in the sedimentary rocks is fundamental to their interpretation from aerial photographs.
- This is due to differential erosion of sedimentary beds.
- Although topographic expression is thus important in recognition of beddings, banding due to vegetation or soil differences, expressed by photographic tone may likewise delineate beds, in absence of topographic expression or in combination with it.

- As seen on aerial photographs shale and similar fine grained rocks tend to have relatively dark color tone, a fine textured drainage and relatively close spaced joints.
- In contrast, coarse grained rocks have relatively light colored, a coarse drainage texture with relatively wide and regularly spaced joints

The type of vegetation may be useful in differentiating specific rock types (see figs. 43 and 61). Hemming (1937) noted that striking vegetation differences were exhibited by limestone and quartzite in northern Rhodesia where the trees *Acacia* and *Albizzia* grew on limestone and *Brachystegia* and *Isoberlinia* grew on quartzite.

- **Unconsolidated materials are readily distinguished on aerial photos with the help of Landforms Like Sand dune. Alluvial fan, cone bazada and similar constructional landforms**
- **Igneous Rocks**
- **Extrusive igneous rocks can be easily distinguished from intrusive rocks based on the landforms, if the terrain is relatively undeformed.**
- **Flow structure in extrusive rock mainly on tertiary and younger age are readily identified from aerial photos. Lobate pattern of vegetation and topography seen at the termination of flows**

- Associated with volcanic cones
- The surface of the flow may be either hummocky or irregular, in contrast to the sedimentary rock where several flows have piled up.
- Intrusive rocks
- It has wide verity of structural relationship to the surrounding rocks.
- Dyke, easily can be revealed from aerial photos based on its resistance to erosion with the surrounding rocks. Also gives contrast tone with the surroundings either difference in rocks type or difference in vegetation cover over dyke.

Terrain Character	Igneous	Sedimentary	Metamorphic
Size & Dimension	Small to Medium	Larger	Moderate
Display of Terrain	Un -Controlled	Perfectly controlled	Moderate Either controlled/uncontrolled
Elevation	Varies point to point without any regularity	Varies uniformly and gradually	Moderate
Topography	Peak & Cliff	No Peaks-Cliffs	Moderate
Orientation/ Terrain	No trend/ orientation	Perfect trend/orientation	Moderate
Surface Smoothness	Rugged	Smooth	Smooth & Rugged

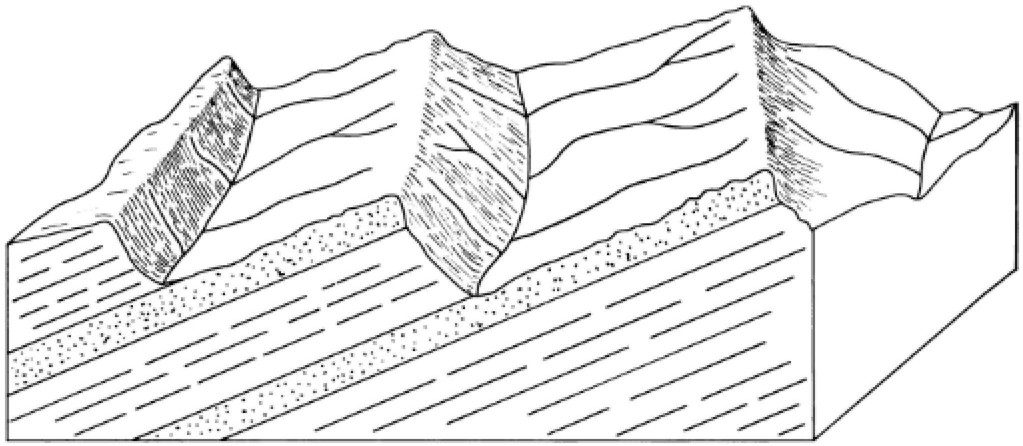


FIGURE 5.—Sketch showing long tributary streams on updip side of strike valley in area of low dips.

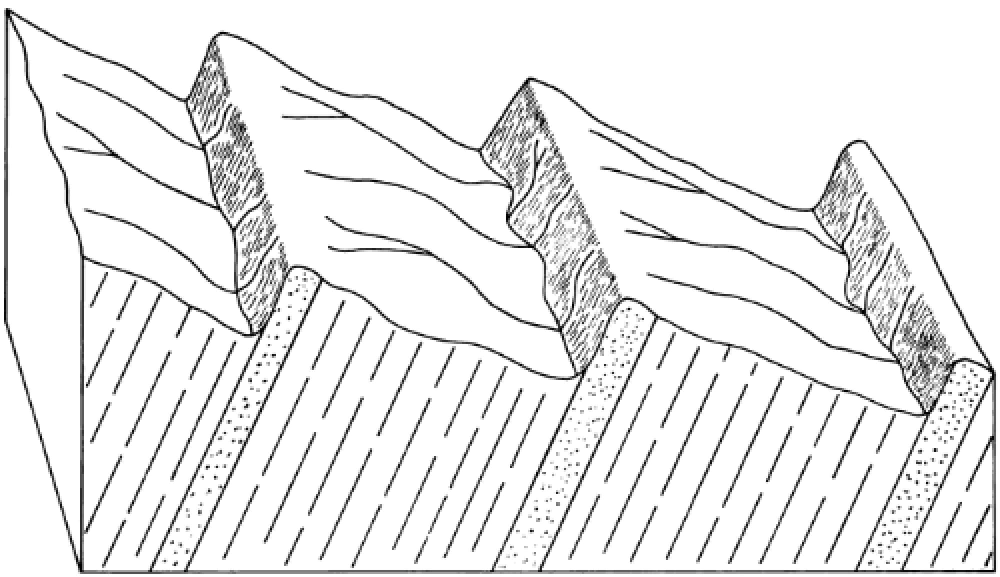


FIGURE 6.—Sketch showing long tributary streams on downdip side of strike valley in area of steep dips.

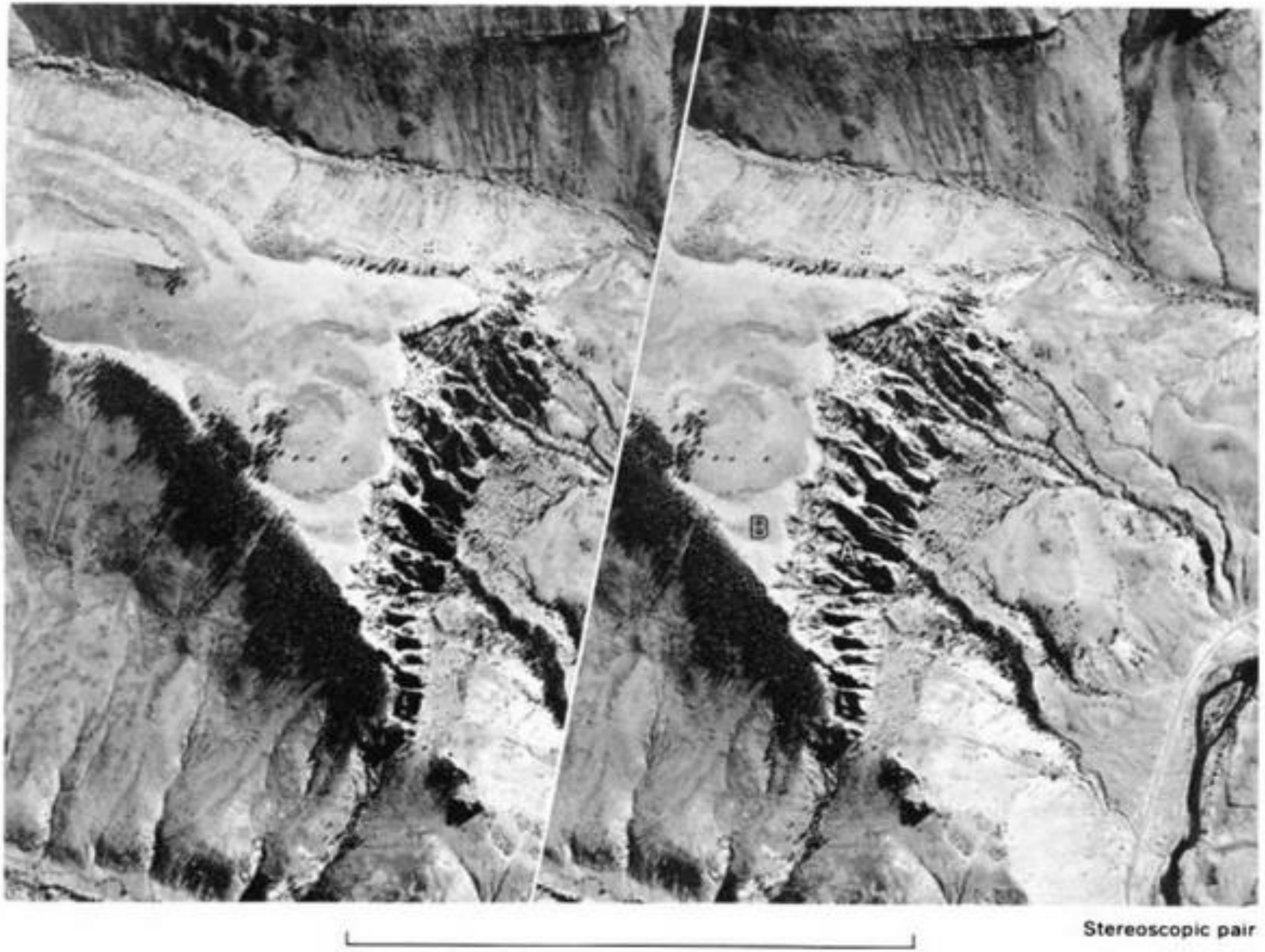


FIGURE 39.—POORLY RESISTANT PYROCLASTIC ROCKS OVERLAIN BY RESISTANT CAPPING FORMATION (COLORADO).

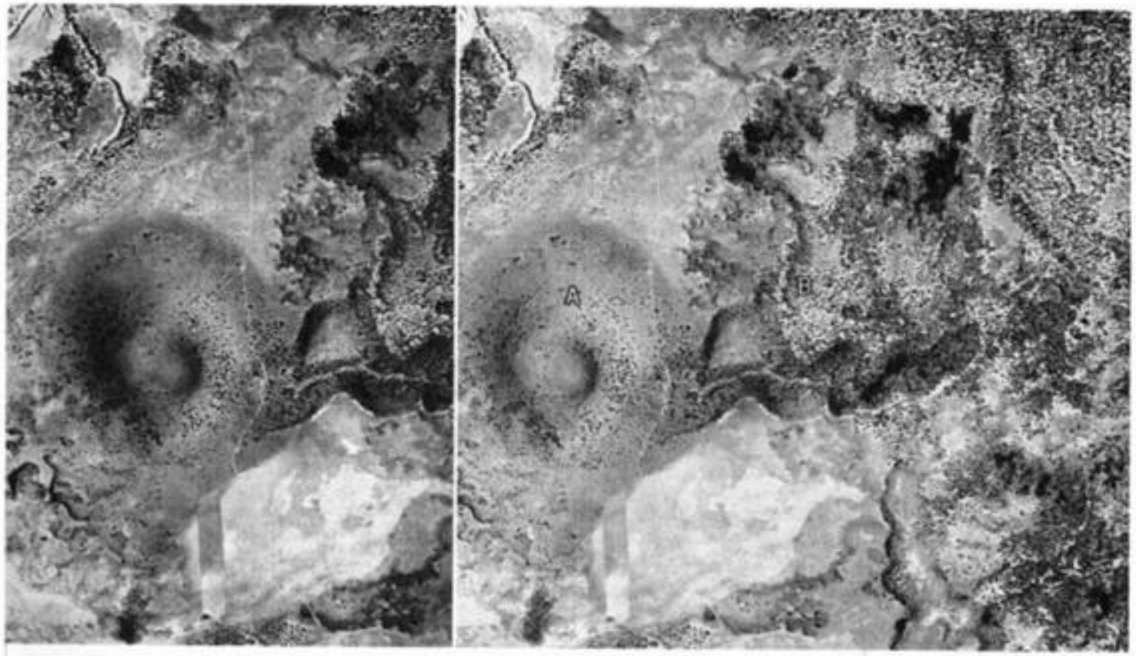


FIGURE 41.—EXTRUSIVE VOLCANIC ROCKS AND ASSOCIATED CINDER CONE (UTAH).

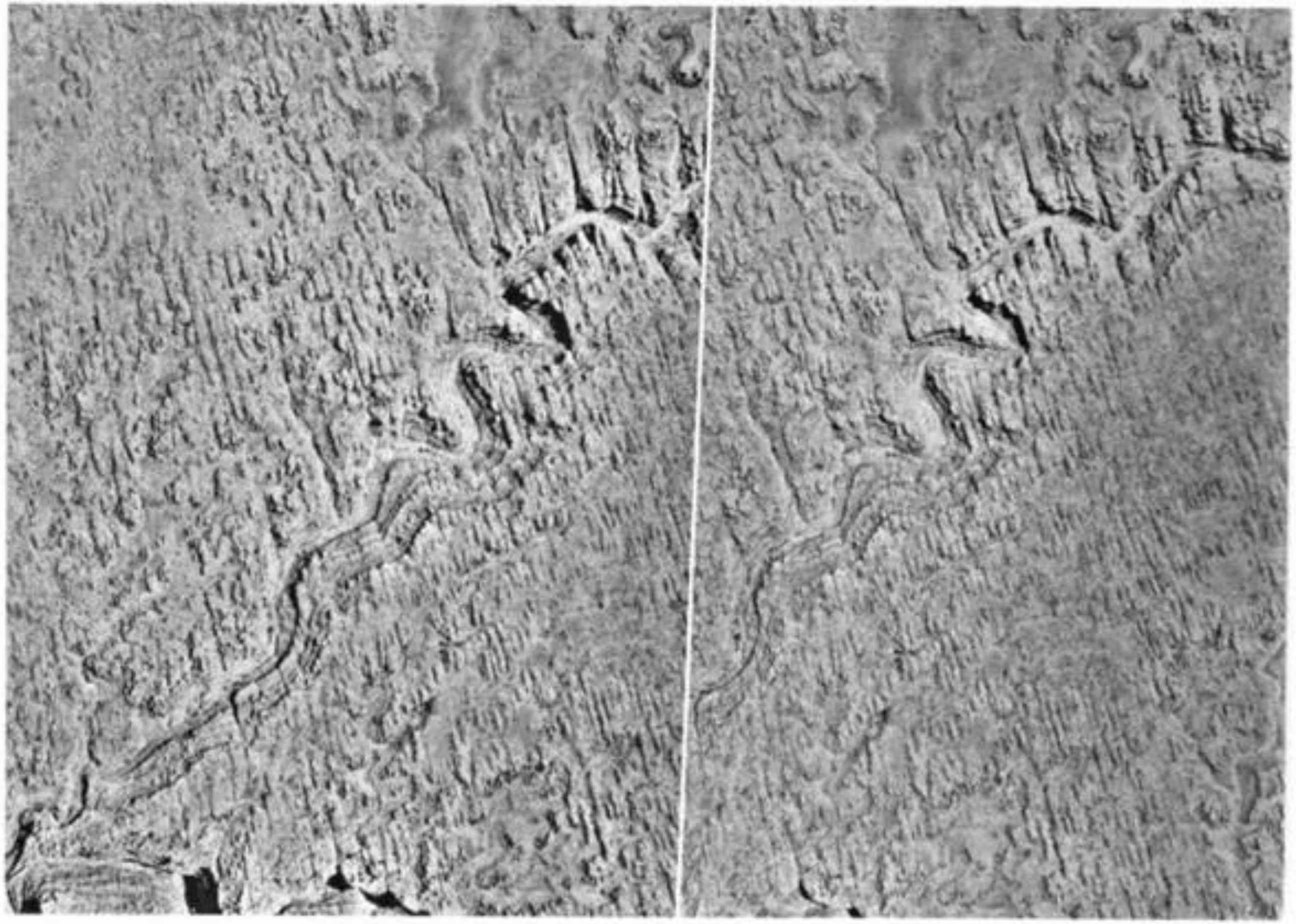


FIGURE 42.—FLAT-LYING SANDSTONE (SOUTHERN UTAH).

Prominent wide-spaced joints are shown by many short lineations. Where beds are essentially flat lying, joints commonly form in a right-angle pattern and give the terrain a blocky appearance locally, although one direction of jointing may dominate and give a conspicuous linearity to the topographic grain. The light photographic tone and coarse-textured drainage is typical of coarse sedimentary rocks. Major drainage is dendritic; this pattern is commonly characteristic of flat-lying rocks. Minor drainage is controlled by joints.

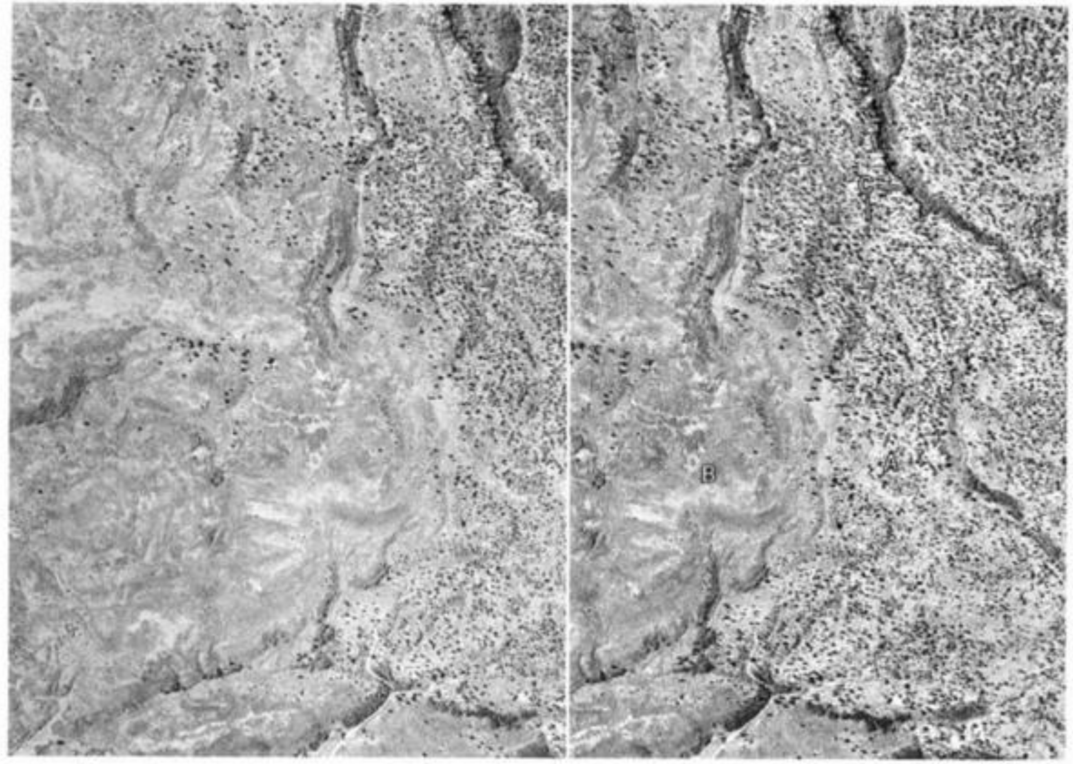


FIGURE 43.—SANDSTONE AND CONGLOMERATE BEDS INTRUDED BY DIORITE PORPHYRY LACCOLITH (UTAH).

Approximately 1 mile

FIGURE 43.—SANDSTONE AND CONGLOMERATE BEDS INTRUDED BY DIORITE PORPHYRY LACCOLITH (UTAH).

[Approximate scale 1 : 20,000. Photographs by Commodity Stabilization Service]

Conspicuous contrast in vegetation results from different lithologic types. Sandstone and conglomerate beds, *A*, are covered largely with scattered tall jack, yellow, and ponderosa pine trees. Diorite porphyry, *B*, is covered with scrub oak as much as 10 feet high. This dense growth of scrub oak forms a photographic texture that contrasts with areas covered with pines. Note serrated edges of bluffs, *C*, which are expressions of joints in sandstone and conglomerate beds.

Mapping of Geology

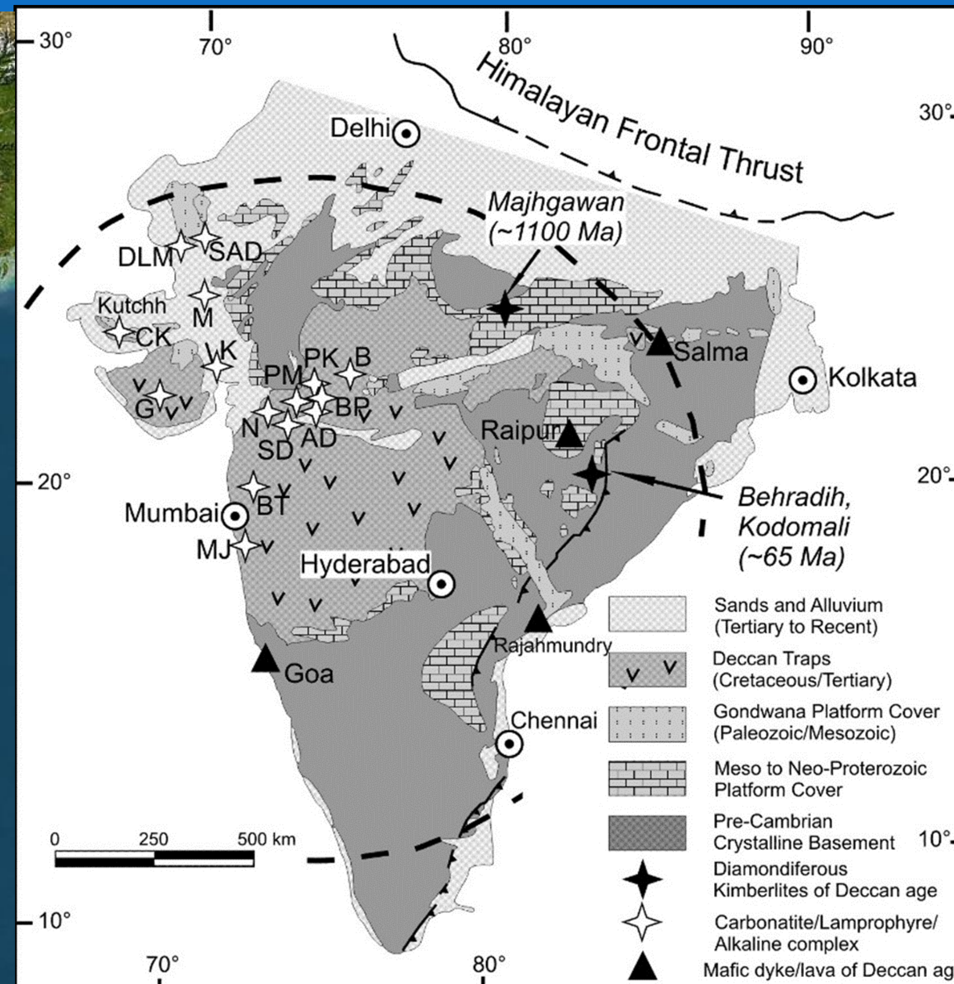
The Mapping of Geology included

- Lithology
- Structure
- MInerals


©PlanetObserver

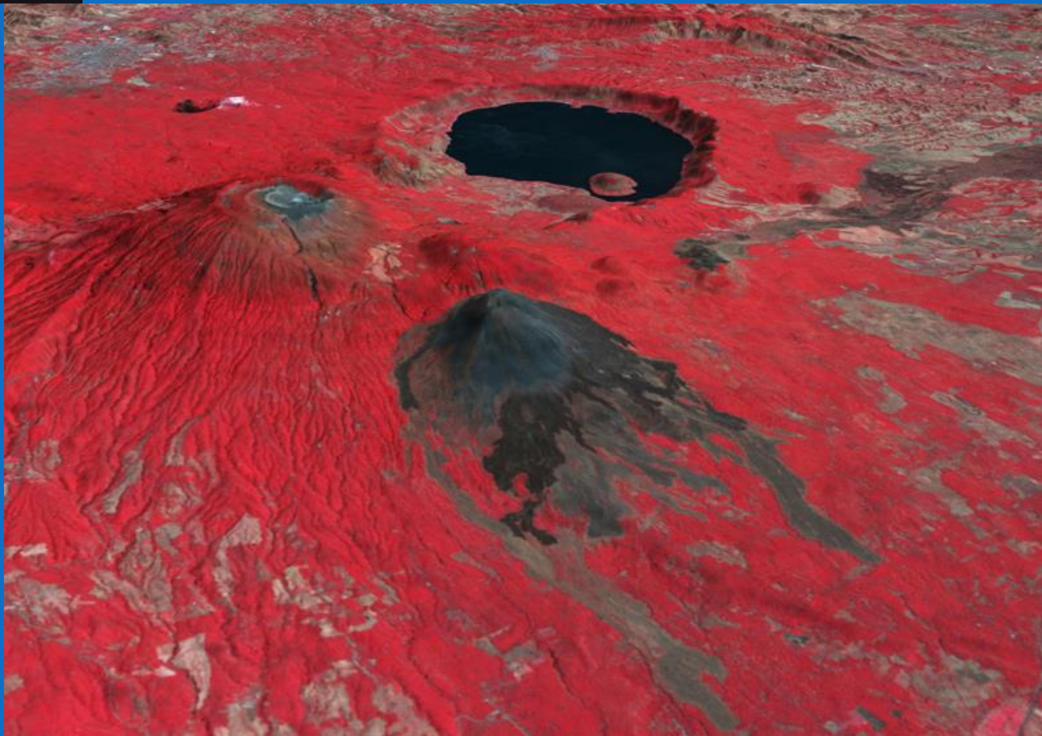
Lonar Lake is a saline soda lake located at Lonar in Buldana district, Maharashtra, India, which was created by a **meteor impact** during the Pleistocene Epoch.

Tonal variation for Igneous volcanic rock

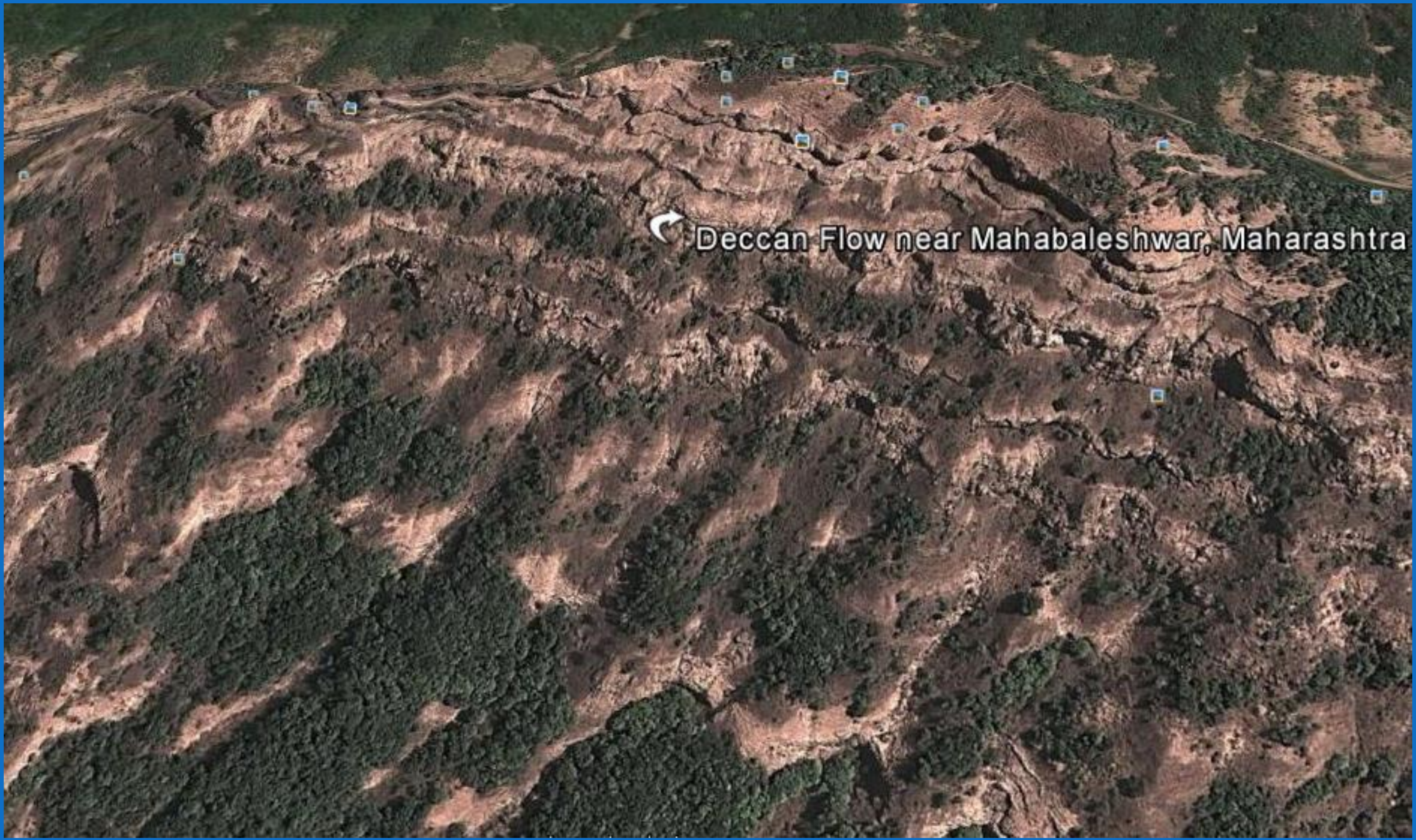


30°
70°
80°
90°
30°
Himalayan Frontal Thrust
Delhi
Majhgawan
(~1100 Ma)
DLM
SAD
Kutchh
M
CK
K
PK
B
PM
G
BP
N
AD
SD
Salma
Kolkata
Raipur
20°
20°
Behradih,
Kodomali
(~65 Ma)
Mumbai
BT
MJ
Hyderabad
Rajahmundry
Goa
Chennai
0
250
500 km
10°
10°
70°
80°
Sands and Alluvium
(Tertiary to Recent)
Deccan Traps
(Cretaceous/Tertiary)
Gondwana Platform Cover
(Paleozoic/Mesozoic)
Meso to Neo-Proterozoic
Platform Cover
Pre-Cambrian
Crystalline Basement
Diamondiferous
Kimberlites of Deccan age
Carbonatite/Lamprophyre/
Alkaline complex
Mafic dyke/lava of Deccan ag

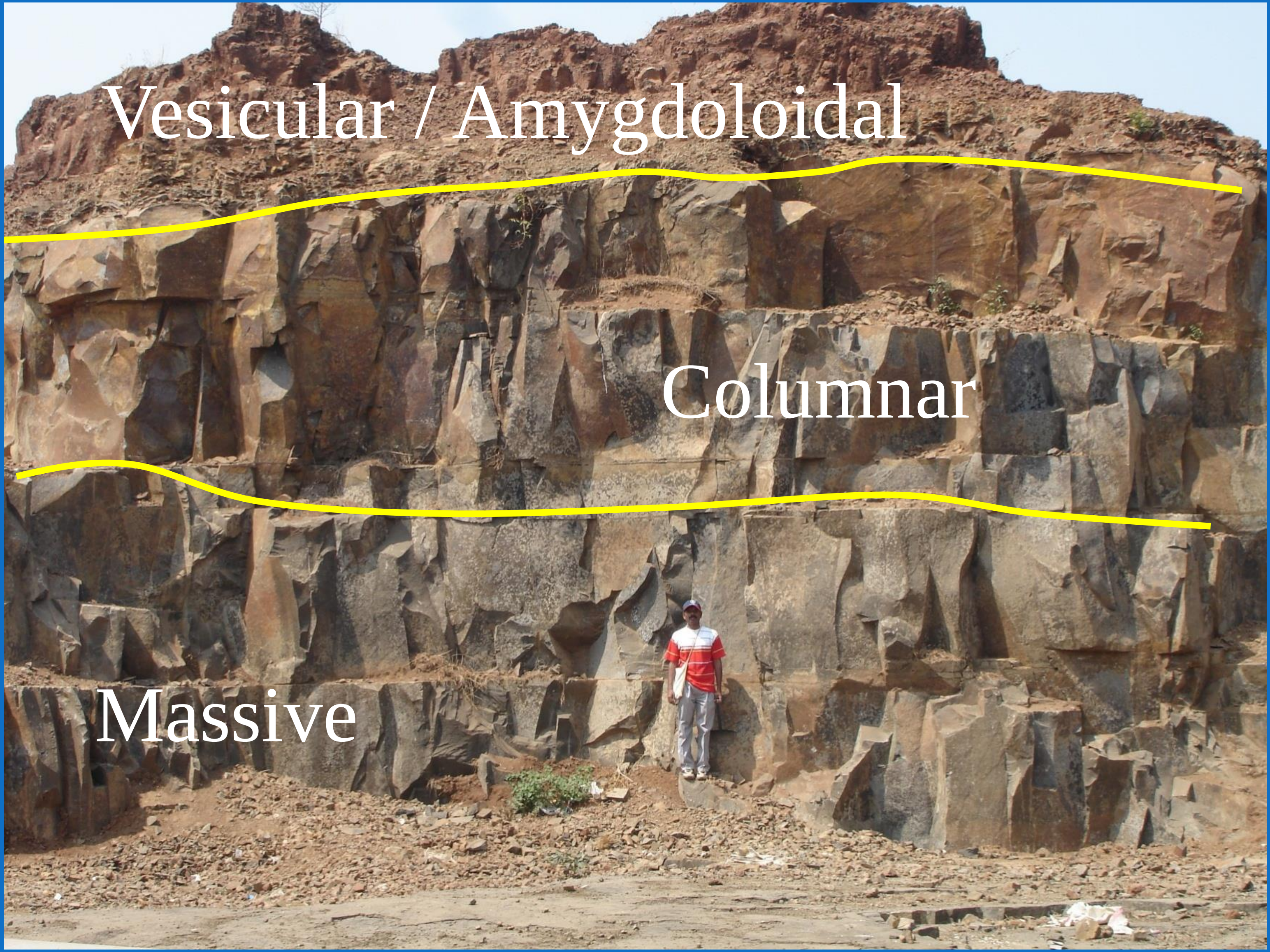

Lake Nicaragua
N
Moyogalpa
Concepcion
Esquipulas
San Jose
del Sur
El Corozal
Maderas
San Jorge
San Ramon
La Virgen
Pan American Hwy



Multiple flows (near Mahabaleshwar, Maharashtra)



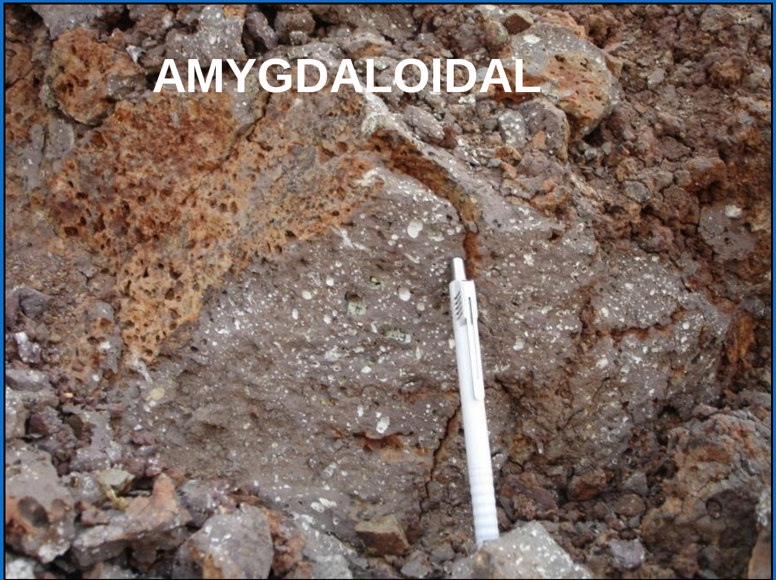
Near Kolhapur

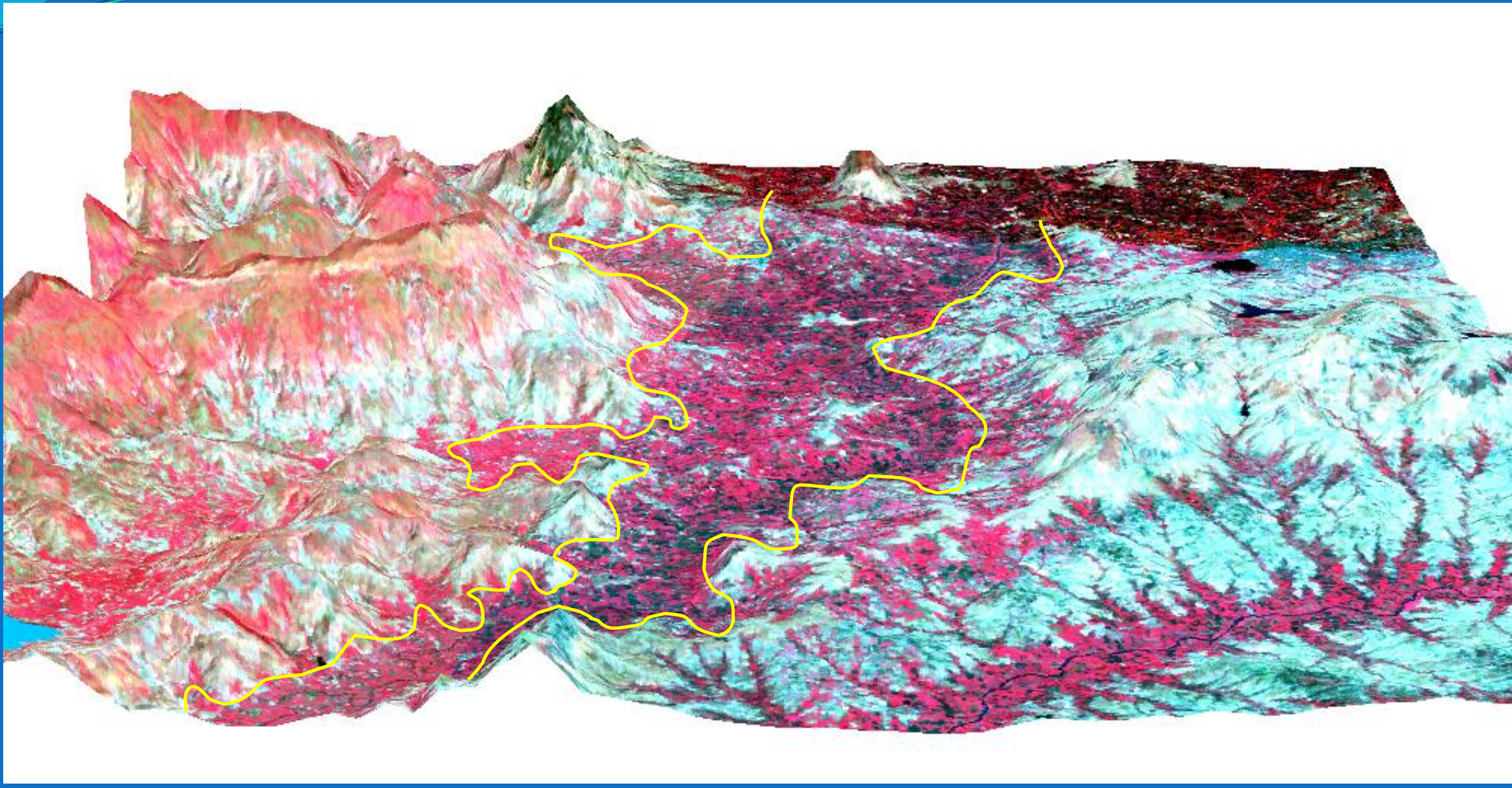

Vesicular / Amygdoloidal
Columnar
Massive


MASSIVE

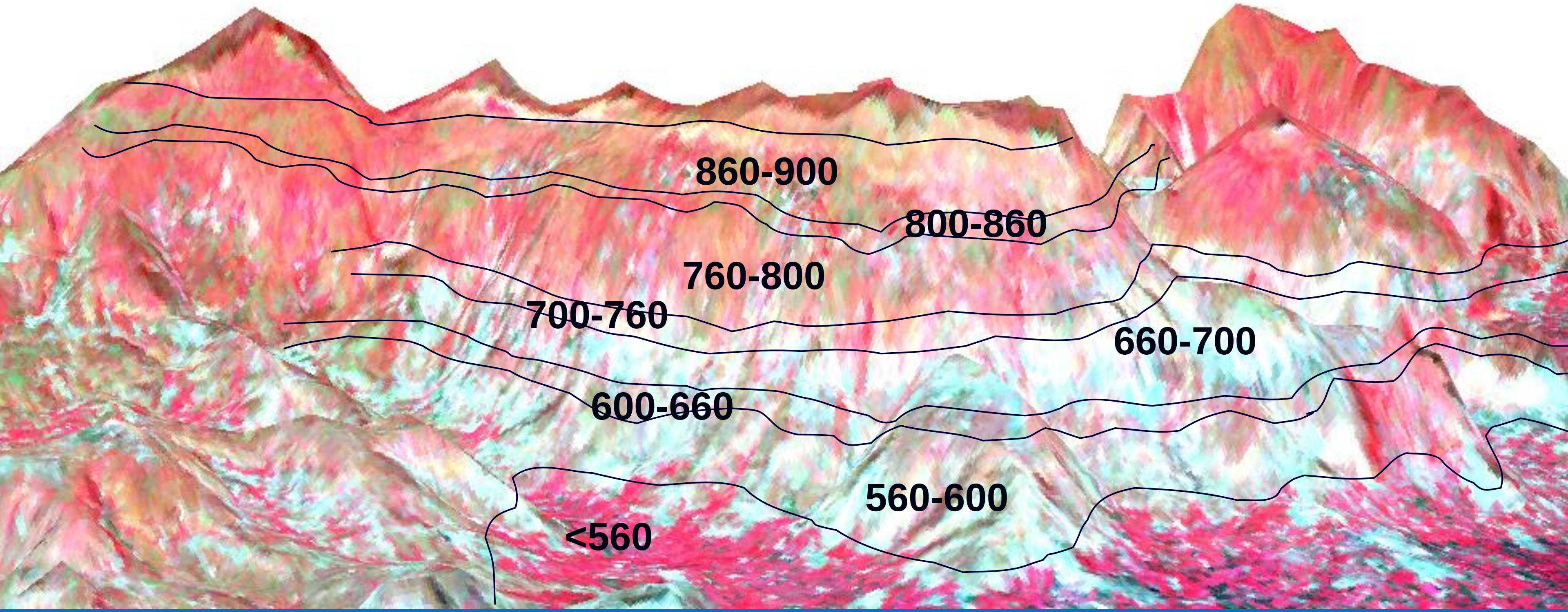

COLUMNAR


VESICULAR


AMYGDALOIDAL



DEM Wrapped FCC image showing different level of flow elevation




Country : Australia
Area : Ayers Rock, Northern Territory
Sensor : IKONOS
Resolution (GSD) : 1 meter
Sedimentary rock
Showing vertical dip
www.satimagingcorp.com
Copyright © GeoEye 2010. All Rights Reser

River section showing different layer of sedimentary rocks

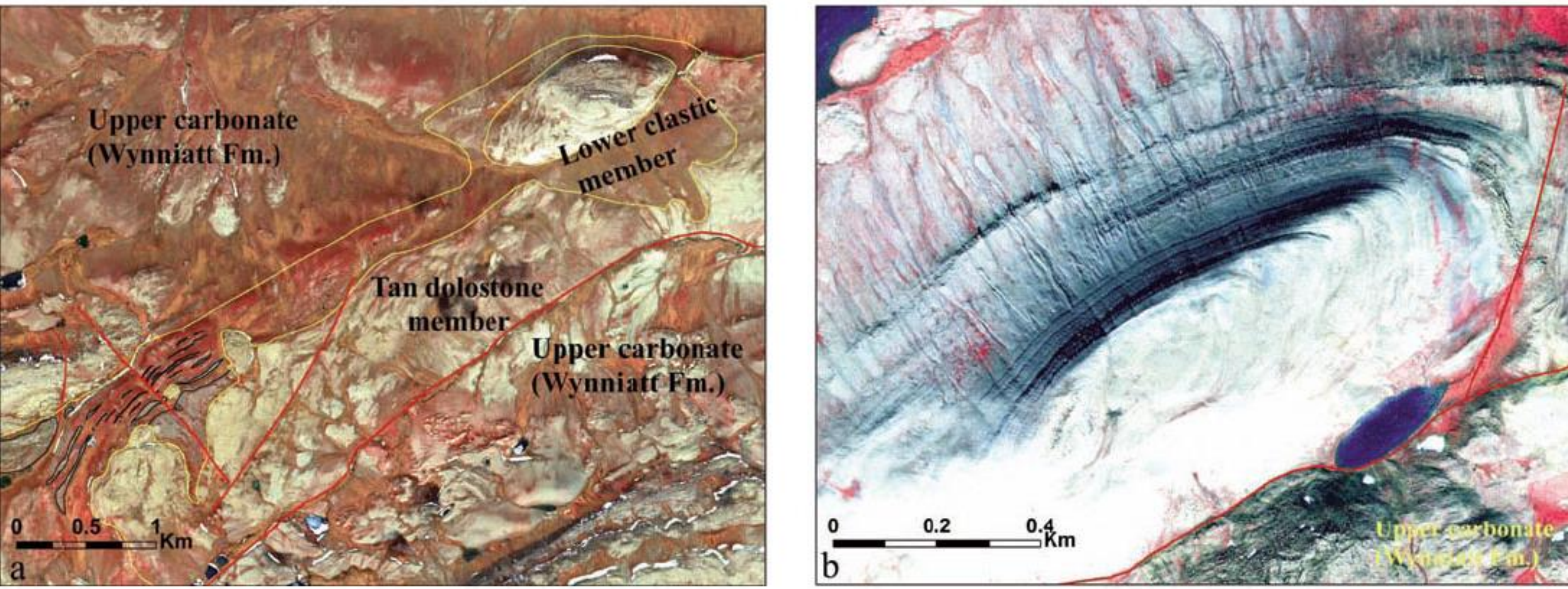
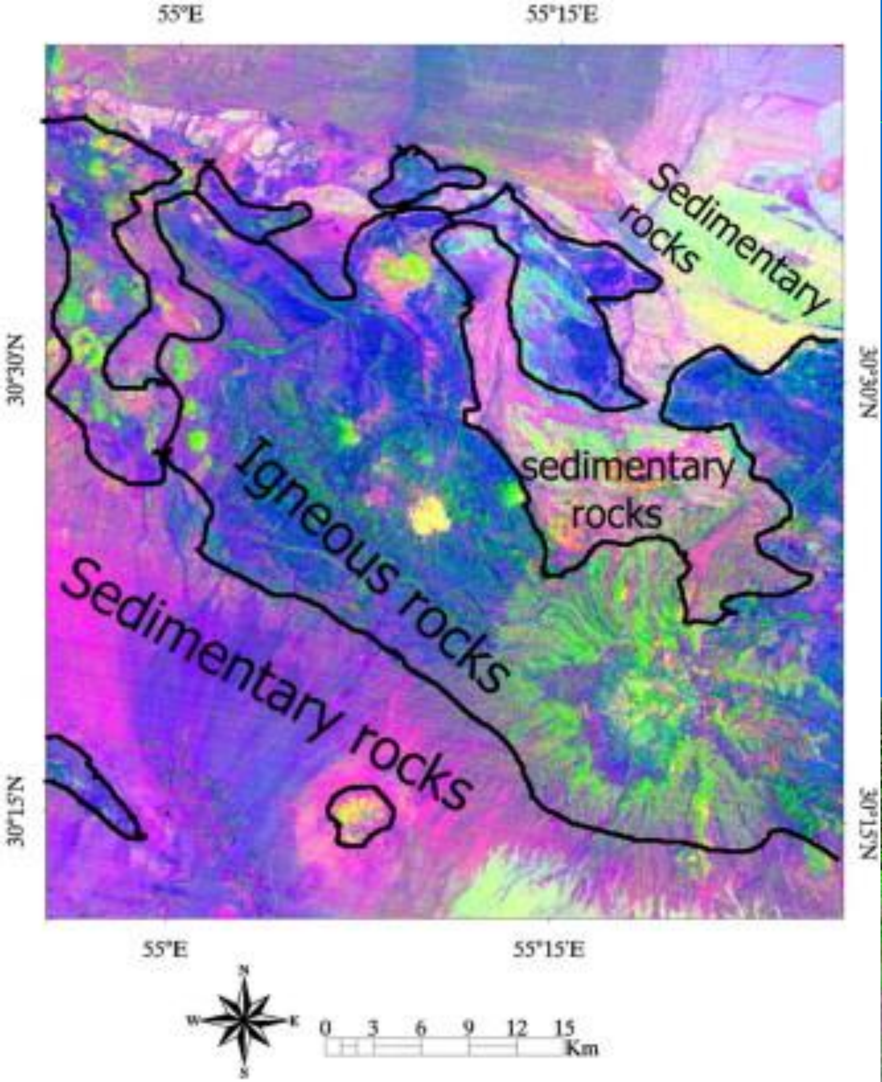
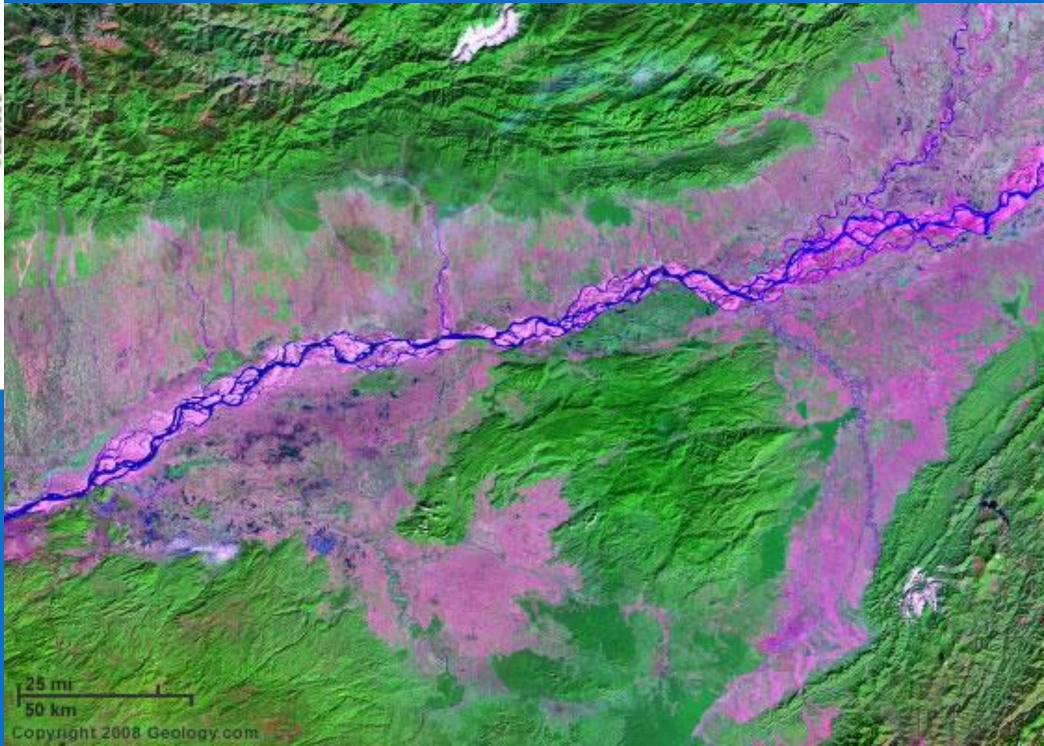
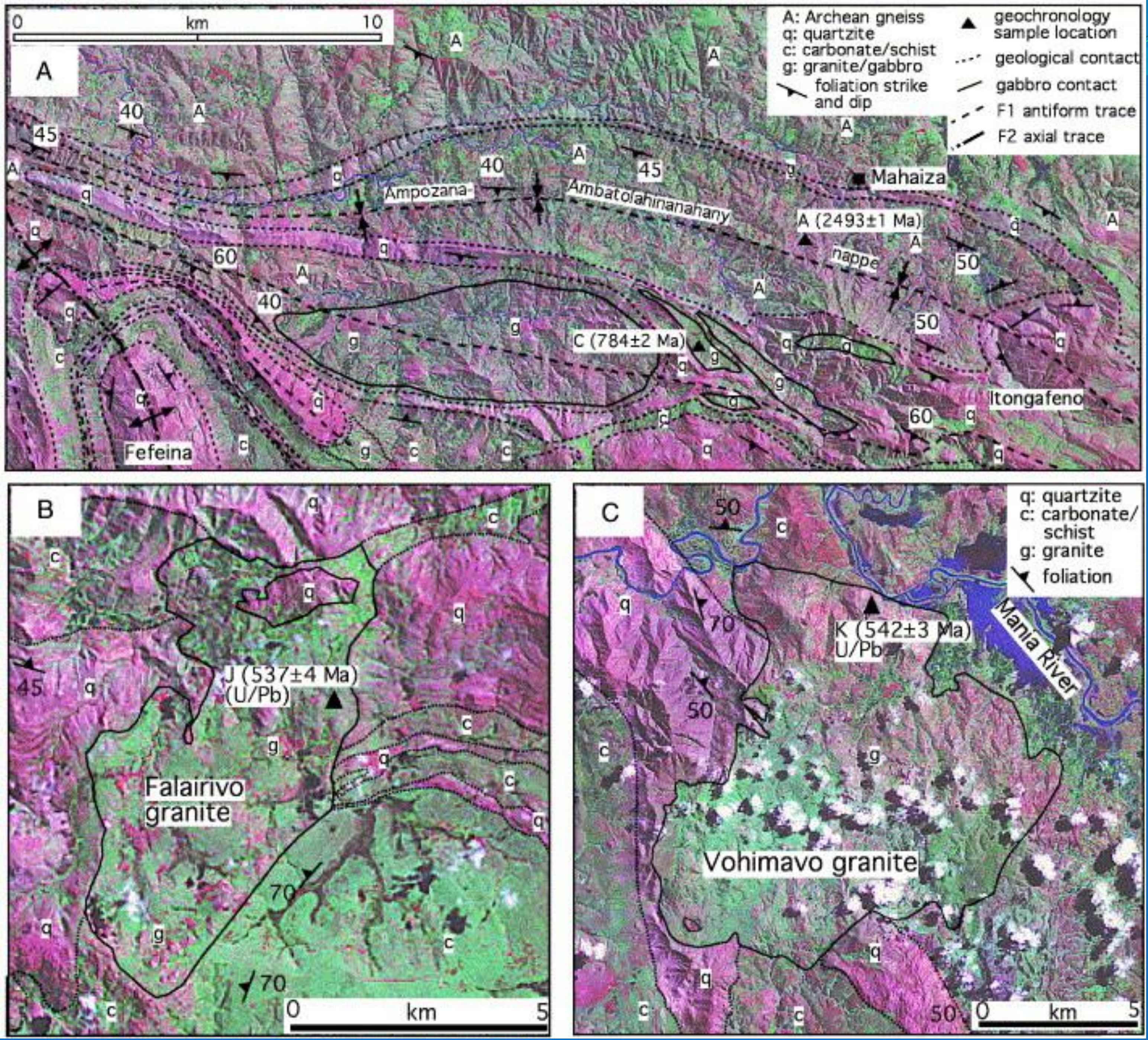


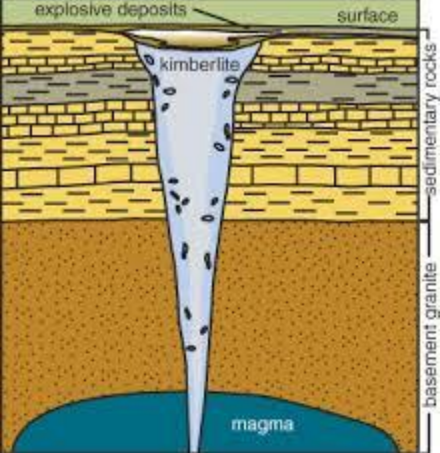
Figure 9. 4,3,2 GeoEye RGB colour composite image (a) A larger scale view of the Cambro Ordovician rocks. The light cream rocks are a tan dolostone member of the Cambrian formation which is clearly distinguished from the lower clastic member comprising quartz-arenite interlayers. The faults and lineaments are shown in red (b) Northeast corner of map area showing details of the Cambro-Ordovician strata.

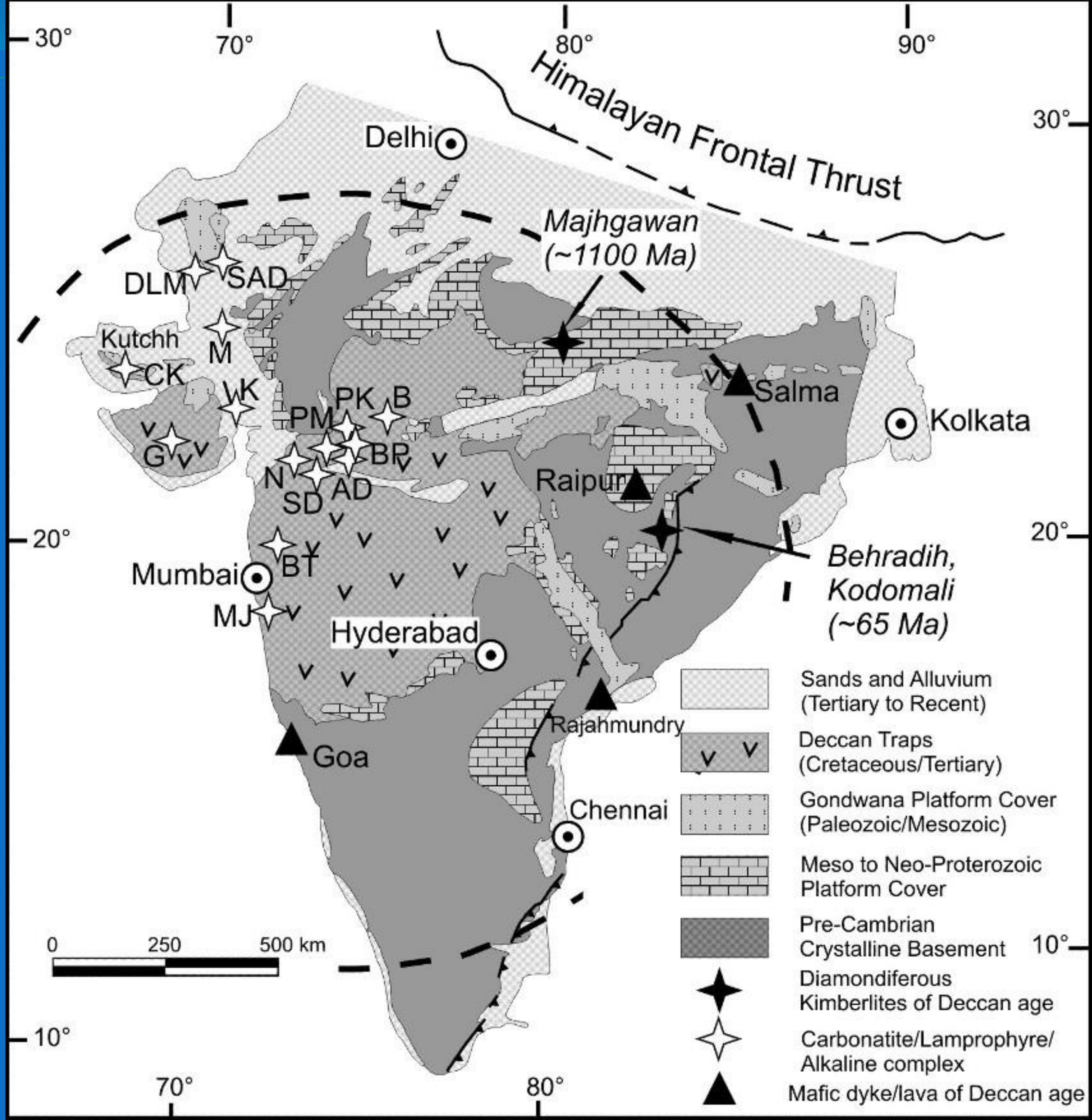

55°E
55°15'E
Sedimentary rocks
30°30'N
sedimentary rocks
Igneous rocks
Sedimentary rocks
30°15'N
55°E
55°15'E
N
W
E
S
0 3 6 9 12 15
Km


25 mi
50 km
Copyright 2008 Geology.com



A
0 km 10
A: Archean gneiss
q: quartzite
c: carbonate/schist
g: granite/gabbro
foliation strike and dip
geochronology sample location
geological contact
gabbro contact
F1 antiform trace
F2 axial trace
Mahaiza
Ampozana-
Ambatolahinanahany
nappe
A (2493±1 Ma)
C (784±2 Ma)
Itongafeno
Fefeina
B
J (537±4 Ma) (U/Pb)
Falairivo granite
0 km 5
C
q: quartzite
c: carbonate/schist
g: granite
foliation
K (542±3 Ma) U/Pb
Mania River
Vohimavo granite
0 km 5


explosive deposits
surface
kimberlite
sedimentary rocks
basement granite
magma


Himalayan Frontal Thrust
Delhi
Majhgawan
(~1100 Ma)
DLM
SAD
Kutchh
M
CK
K
PK
B
PM
G
BP
N
AD
SD
Salma
Kolkata
Raipur
Behradih,
Kodomali
(~65 Ma)
BT
Mumbai
MJ
Hyderabad
Rajahmundry
Goa
Chennai
0
250
500 km
Sands and Alluvium
(Tertiary to Recent)
Deccan Traps
(Cretaceous/Tertiary)
Gondwana Platform Cover
(Paleozoic/Mesozoic)
Meso to Neo-Proterozoic
Platform Cover
Pre-Cambrian
Crystalline Basement
Diamondiferous
Kimberlites of Deccan age
Carbonatite/Lamprophyre/
Alkaline complex
Mafic dyke/lava of Deccan age
30°
70°
80°
90°
20°
10°

Lithology

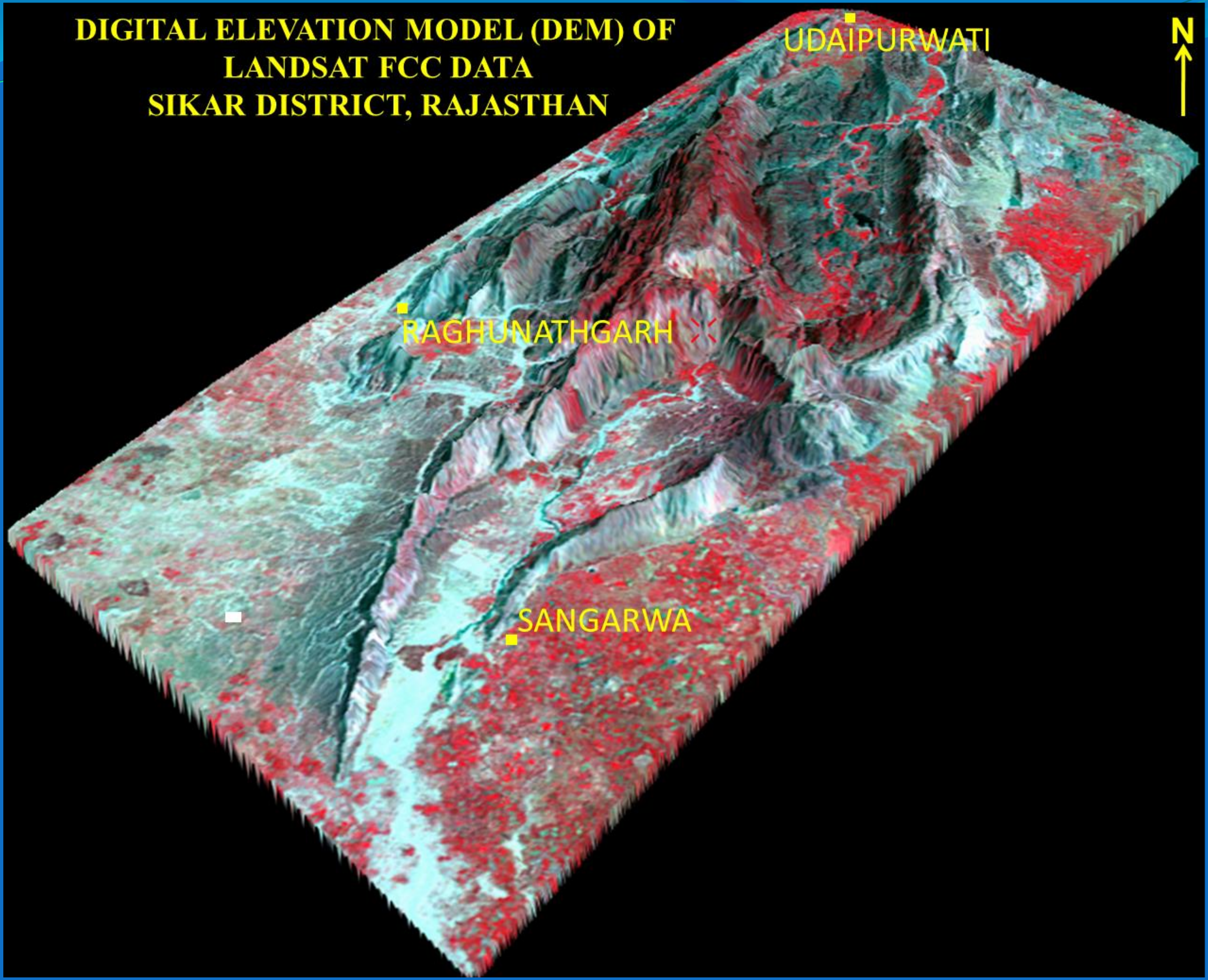
Table - 5.1: Classification of rock types / lithologic units

Rock Group	Code No.	Rock Type / Lithologic Unit
UNCONSOLIDATED SEDIMENTS	11	Alluvium – sand/silt dominant
	12	Alluvium – clay dominant
	13	Alluvium – sand/silt & clay alternating beds
	14	Colluvium – clay/silt dominant
	15	Colluvium – pebble/cobble dominant
	16	Eolian sand / silt
	17	Loess
	18	Alluvium – Gravel dominant
	19	-----------
RESIDUAL CAPPINGS	21	Laterite (ferricrete)
	22	Bauxite (alecrete)
	23	Kankar (calcrete)
	24	Chert (silcrete)
	25	Detrital laterite / bauxite
	26	------------

DECCAN TRAPS & INTERTRAPPEANS	31	Inter-/Infra-trappean sand / clay beds
	32	Tuffacious basalt
	33	Vesicular basalt
	34	Amygdaloidal basalt
	35	Massive basalt
	36	Columnar basalt
	37	Red / green bole
	38	Unclassified basalt
	39	-----------
OTHER VOLCANICS & METAVOLCANICS	41	Basalt / meta basalt
	42	Rhyolite / meta rhyolite
	43	Dacite / meta dacite
	44	Andesite / meta andesite
	45	Undifferentiated meta basics
	46	Ophiolite / Ophiolite melange
	47	-----------
SEMI-CONSOLIDATED SEDIMENTS	51	Sandstone / pebble bed / conglomerate
	52	Shaly sandstone
	53	Sandstone with shale / coal bands
	54	Sandy shale
	55	Shale with sandstone / limestone bands
	56	Shale / coal / lignite
	57	Limestone / shell limestone
	58	Limestone with shale bands
	59	Cemented assorted mixture of gravel, sand, silt & clay

CONSOLIDATED SEDIMENTS	61	Thin bedded / flaggy sandstone / quartzite
	62	Thick bedded / massive sandstone/ quartzite
	63	Thin bedded / flaggy limestone / dolomite
	64	Thick bedded / massive limestone/ dolomite
	65	Shaly limestone
	66	Shale with limestone/sandstone bands/ lenses
	67	Shale
	68	Conglomerate
	69	Cavernous limestone
PLUTONIC ROCKS	71	Alkaline rocks
	72	Basic rocks
	73	Ultrabasic / ultramafic rocks
	74	-------------
GNEISS-GRANITOID COMPLEX / CHARNOKITE KHONDALITE COMPLEX / MIGMATITE COMPLEX	81	Granites / Acidic rocks
	82	Migmatite / migmatite complex
	83	Granitoid gneiss / gneissic granitoid / granitoid complex
	84	Charnockite
	85	Khondalite
	86	Charnockite-Khondalite complex
	87	-------------

METAMORPHIC ROCKS	91		Gneiss
	92		Schist
	93		Phyllite
	94		Slate
	95		Quartzite
	96		Calc-gneiss / calc-schist
	97		Marble / crystalline limestone
	98		Undifferentiated meta sedimentaries
	99		Undifferentiated Metamorphics
INTRUSIVES	Q	Q	Quartz reef
	P	P	Pegmatite / aplite vein
	D	D	Basic dyke
			Basic sill


DIGITAL ELEVATION MODEL (DEM) OF
LANDSAT FCC DATA
SIKAR DISTRICT, RAJASTHAN
UDAIPURWATI
N
RAGHUNATHGARH
SANGARWA

Structural Features

- ✓ Fold
- ✓ Fault
- ✓ Fracture / Lineament
- ✓ Shear Zone
- ✓ Thrust
- ✓ Joints

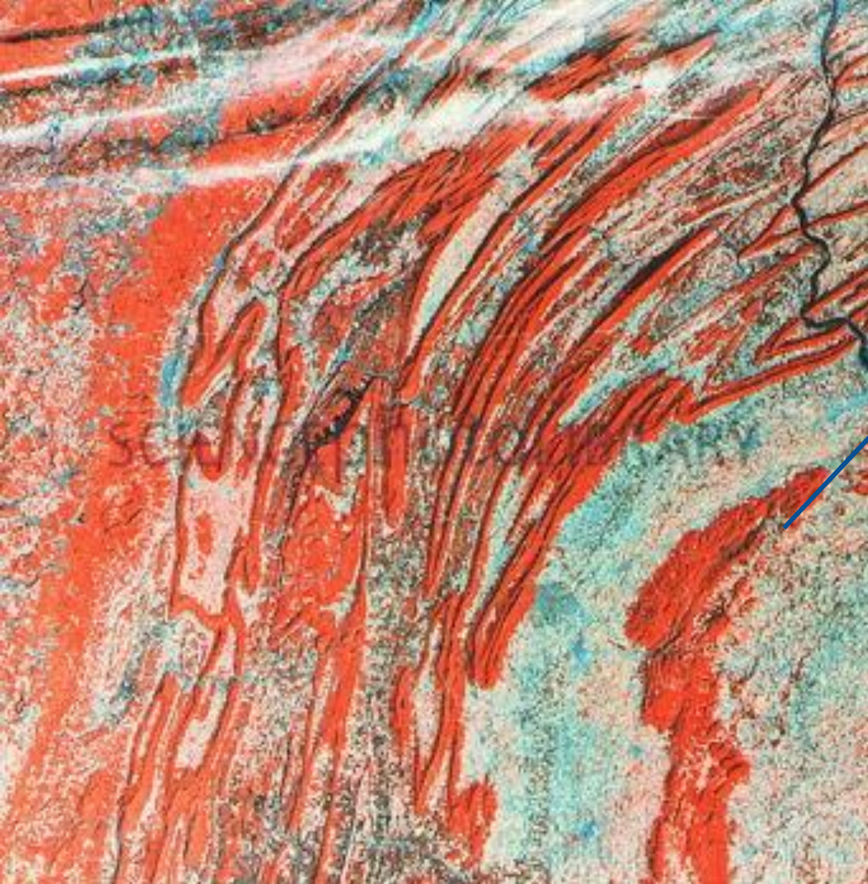
Intrusive Bodies

- ✓ Quartz Reef
- ✓ Pegmatite / Aplite vein
- ✓ Basic Dyke
- ✓ Basic Sill ridge

Mapping of structures from satellite imagery

Folds –

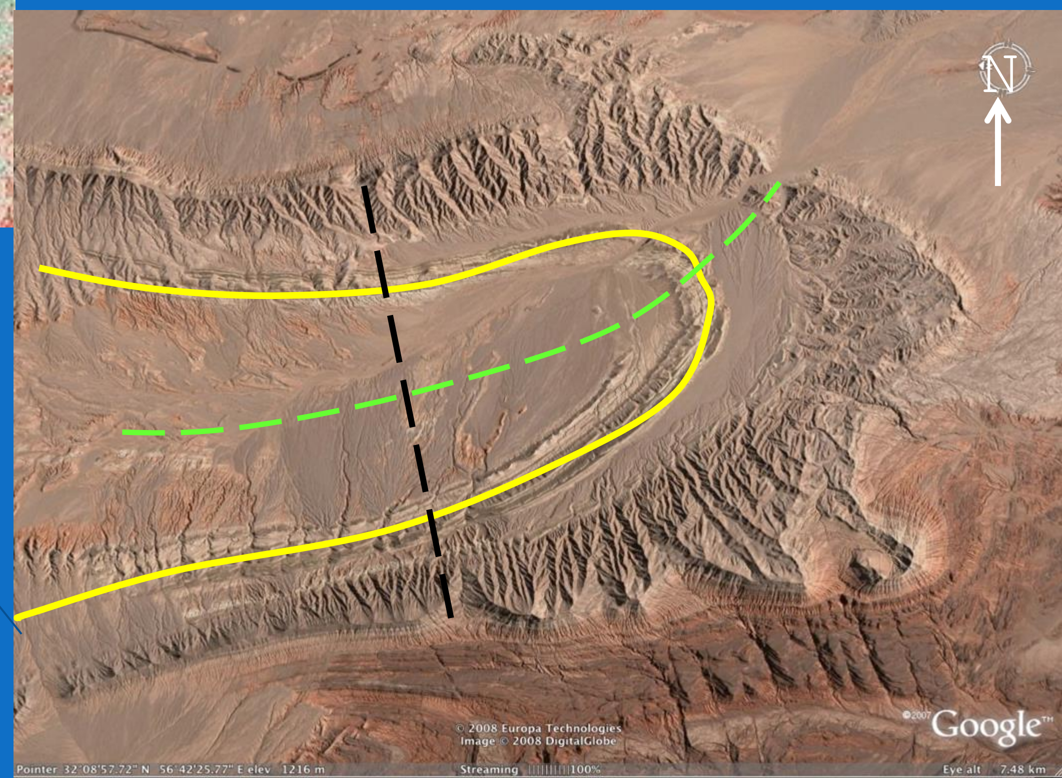
Folds may be defined as **undulations** or **bends** or **curvatures** developed in the rocks of the crust as a result of stresses to which these rock have been subjected from time to time in the past history of the earth.

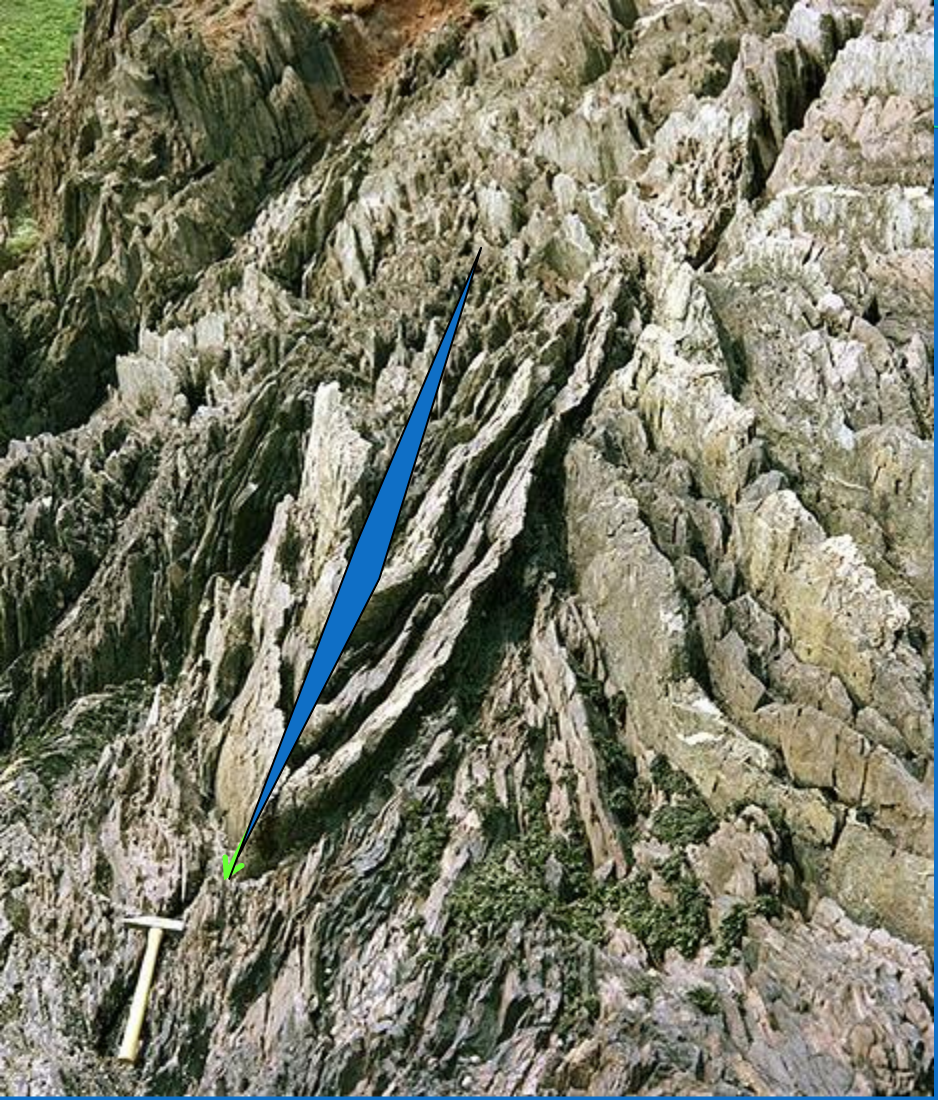


How many fold generations can we interpret from this image?

Find out the rock type?

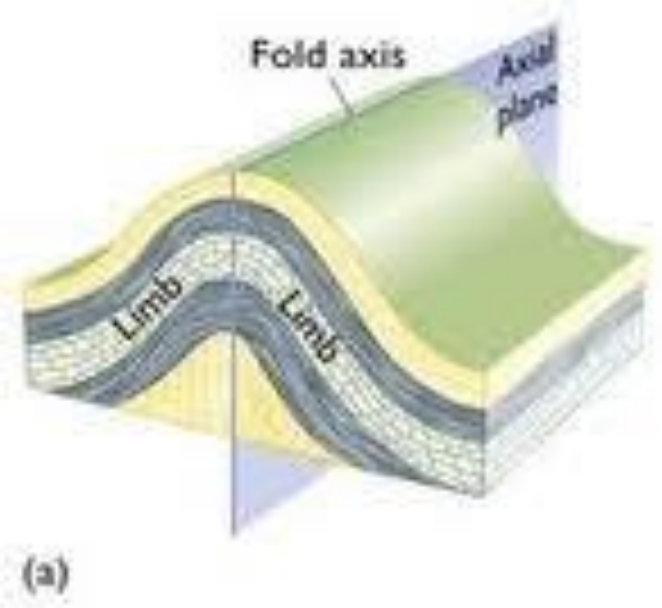
Find out fold axis and axial plane from this Google image.





What type of structure present in this picture?

Is it possible to identify plunge from this picture?



Landsat Imagery showing fold

1. Fold
2. Fault
3. Dyke (generally follow the weak zone)
4. Lineament (linear and curvi-linear)is surface expression of zone of weakness

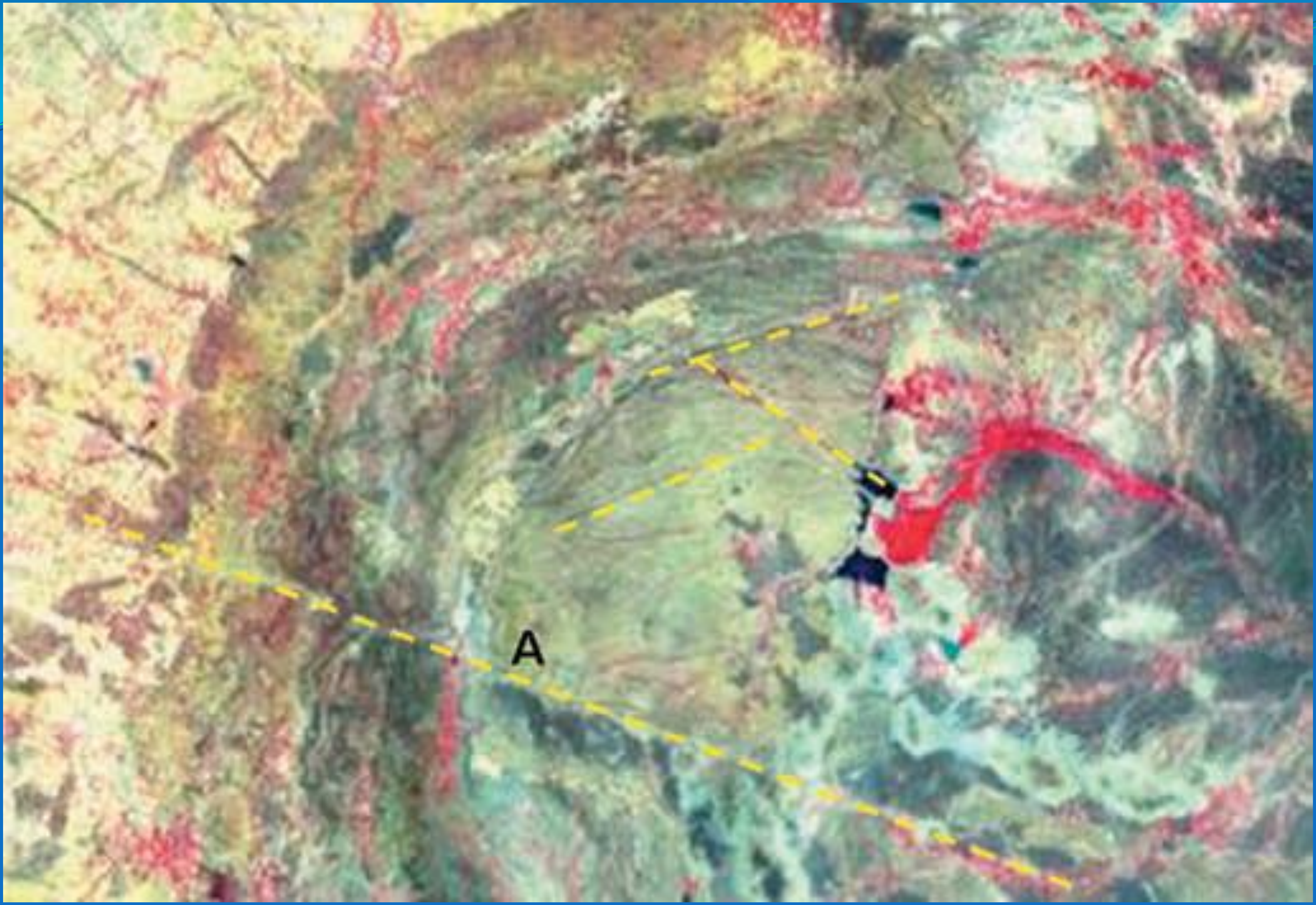

Yachavaram
Magaturu
Ardhaveedu
Donakonda
Kakarla
Near Cuddapah basin, A.P
Jangamguntla
Nagulavaram
Mohiddinpuram
4.75 km
© 2013 Google
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
Google earth
Imagery Date: 2/18/2012 15°39'38.52" N 79°03'33.16" E elev 232 m eye alt 20.75 km

Which one is Younger? Dh1 or Dh2

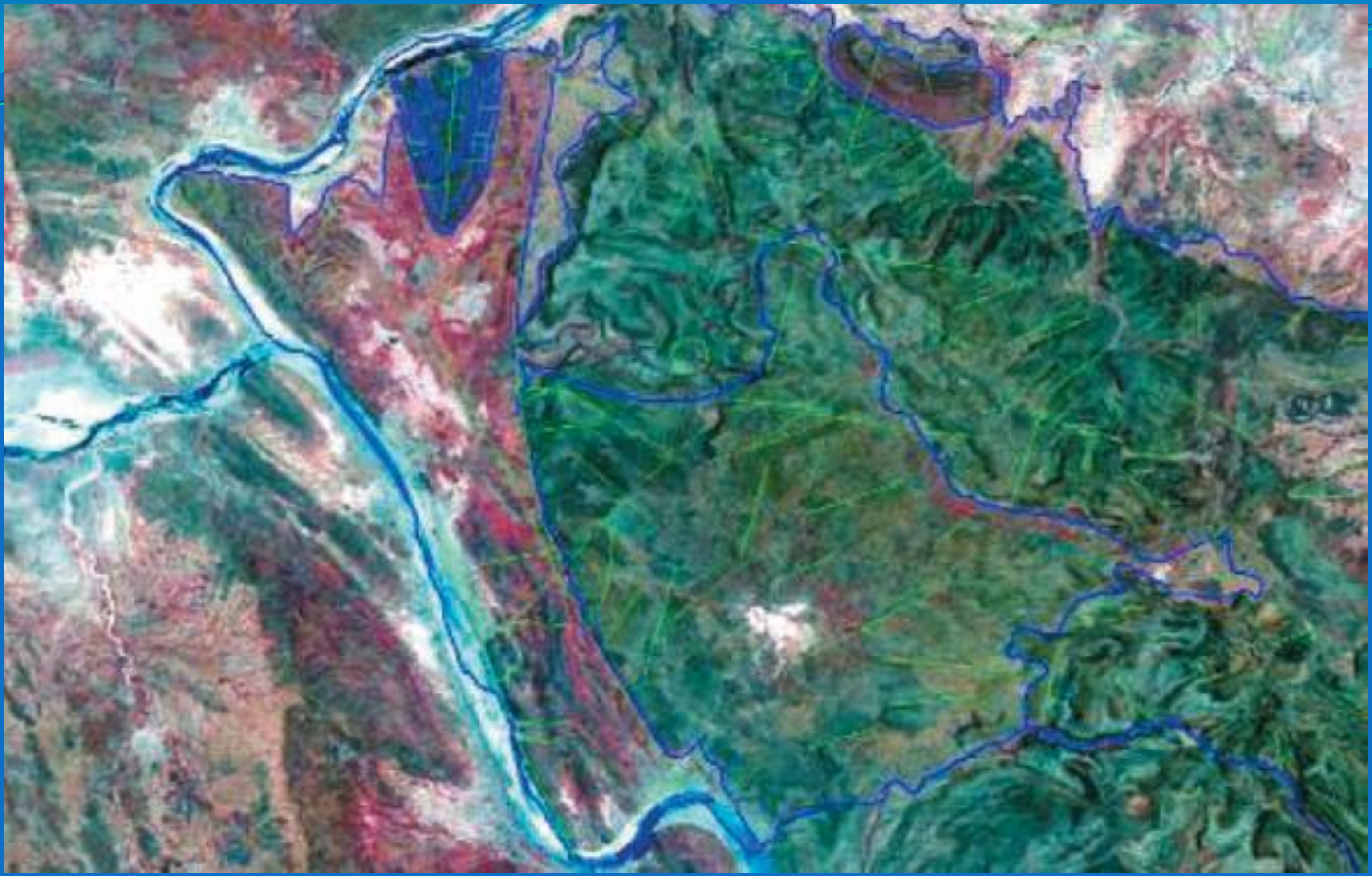

Cajon Pass
Spring
Valley Lake
San Andreas Fault
San Gabriel Mtns
San Bernardino Mtns
Los
Angeles

Paleo path can be established using meander scars and oxbow lakes

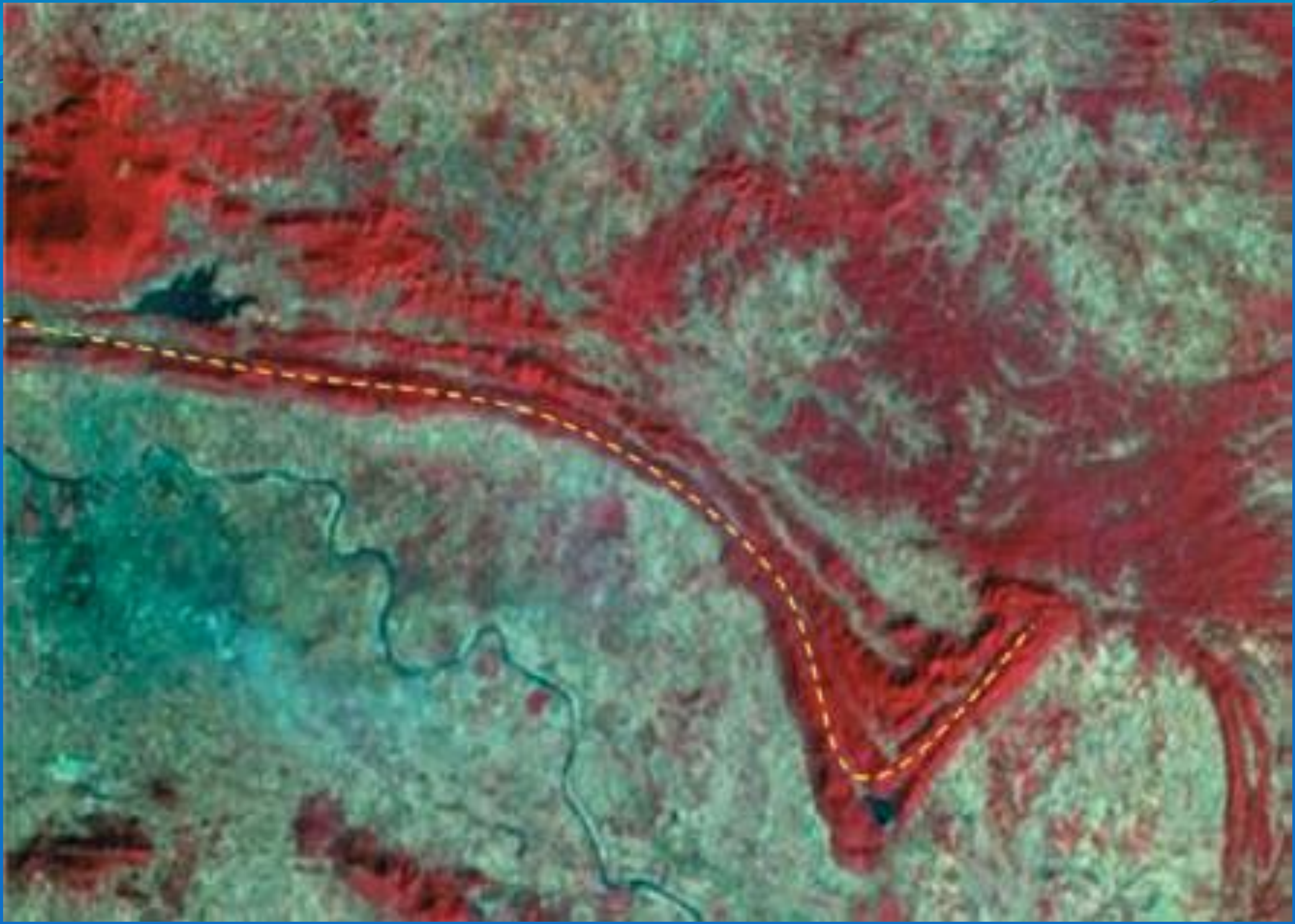
Oxbow Lake can be identified based on the crescent shape and associated features such as meanders using satellite imagery



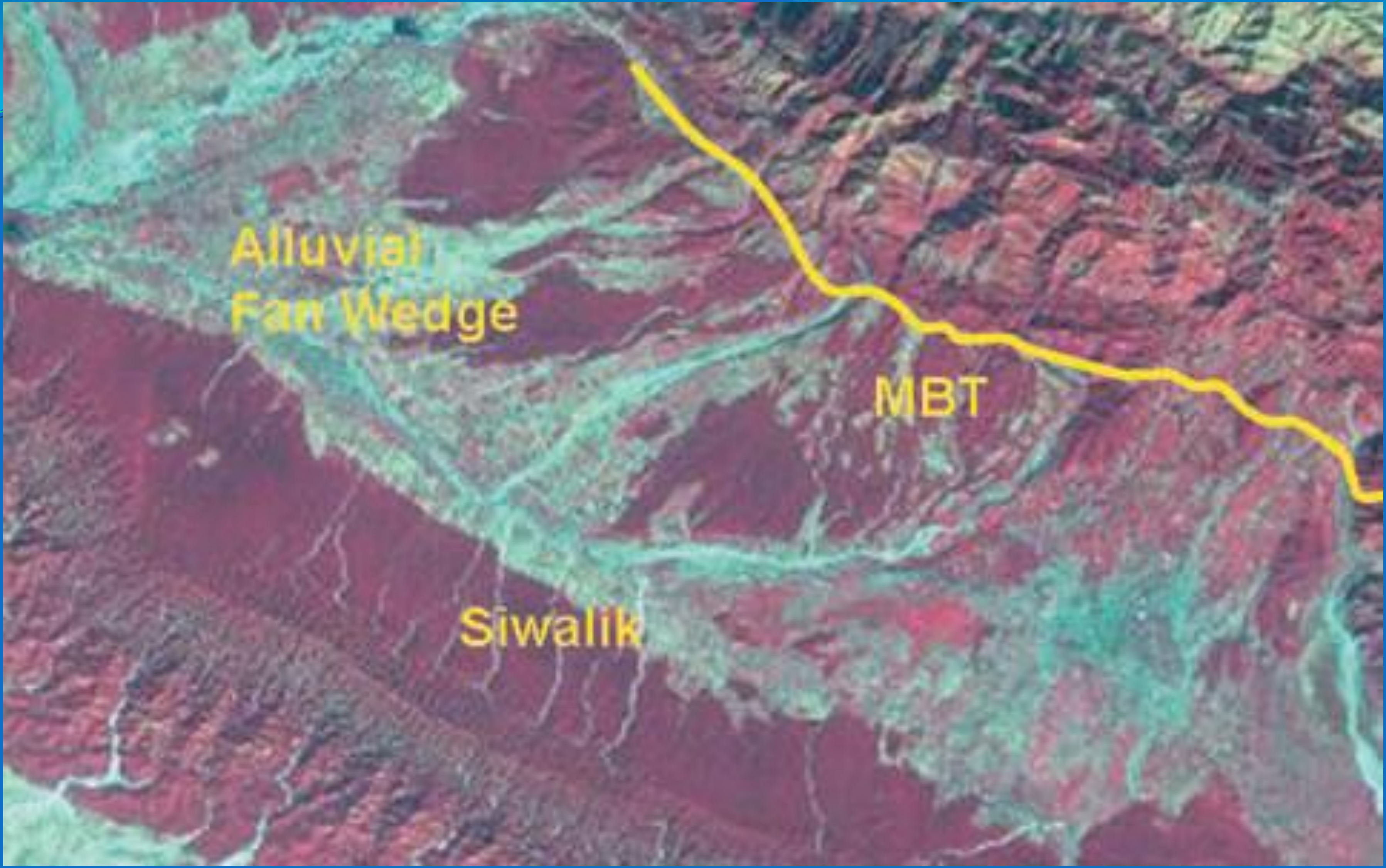
Fracture marked by yellow colour in parts of Kurnool basin. A mega fault with length more than 3 Km is marked at ‘A’.



Structural hills (SH) in part of South Bastar district, Chhattisgarh state. The structural hills are made up of various lithounits viz., phyllite/schist (Phy), sandstone (SSt) and quartzite (Qtz). Granite gneisss (Gr-Gn) form the pediplains seen in the NE corner of the image. Number of geological structures, viz., folds, faults & lineaments/fractures are mapped in the SH.

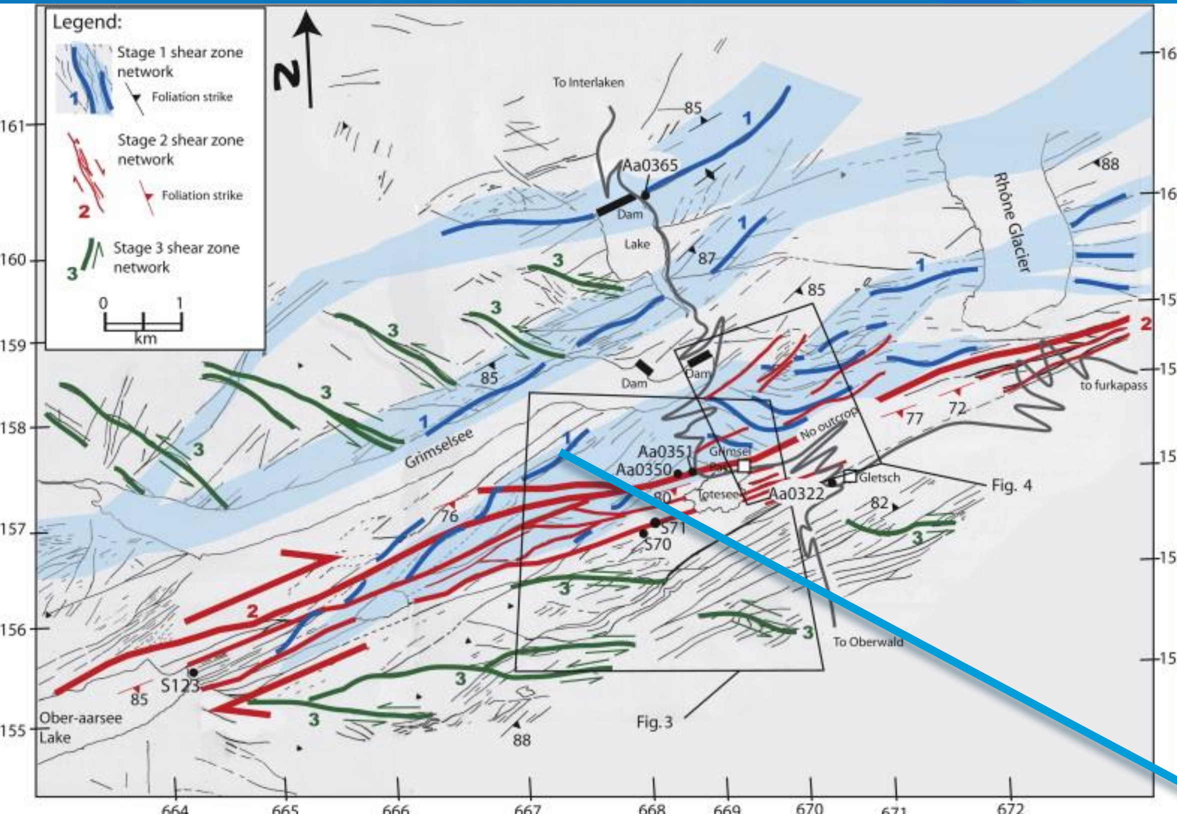


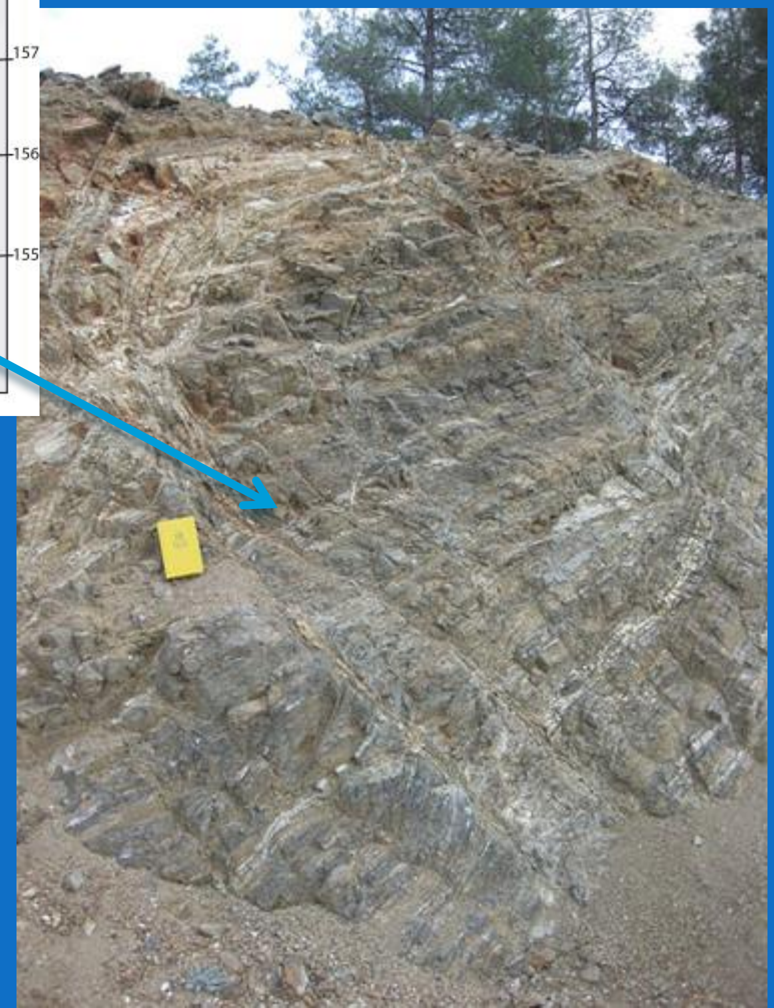
Singhbhum thrust zone marked in yellow colour. It’s a mega thurst.



Main Boundary Fault (thrust fault) in IRS P6 LISS III data.

Shear Zone


Legend:
Stage 1 shear zone network
Foliation strike
Stage 2 shear zone network
Foliation strike
Stage 3 shear zone network
0 1
km
N
To Interlaken
Aa0365
Dam
Lake
Rhône Glacier
Dam
Dam
Grimselsee
Aa0351
Aa0350
Grimsel Pass
Totesee
Aa0322
Gletsch
No outcrop
to furkapass
Fig. 4
S71
S70
S123
Ober-aarsee Lake
Fig. 3
To Oberwald
161
160
159
158
157
156
155
664
665
666
667
668
669
670
671
672



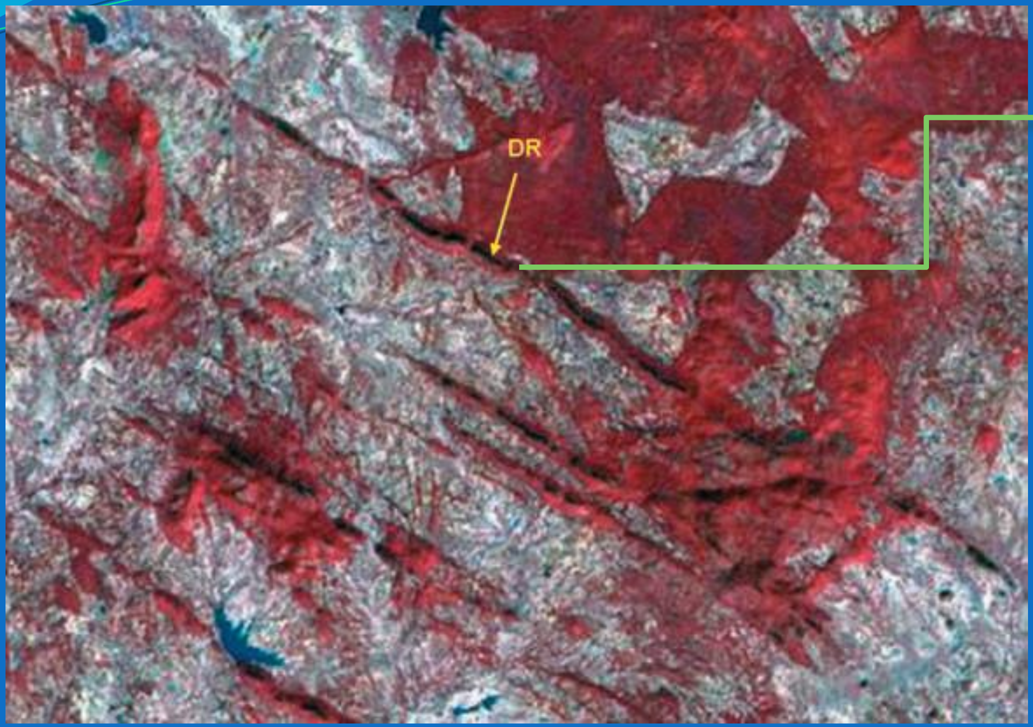
This is a peak in the Snowy Mountains of Wyoming. It is composed of very old quartzites (once quartz rich sandstones) that have been deformed and metamorphosed. The quartzite layers form the large relatively flat cliff faces steeply dipping toward the viewer. They are intensely cracked by relatively straight fracture sets known as joints. Climbers are especially attuned to these joint sets. The form of this mountain is due to fracture controlled erosion

DYKES

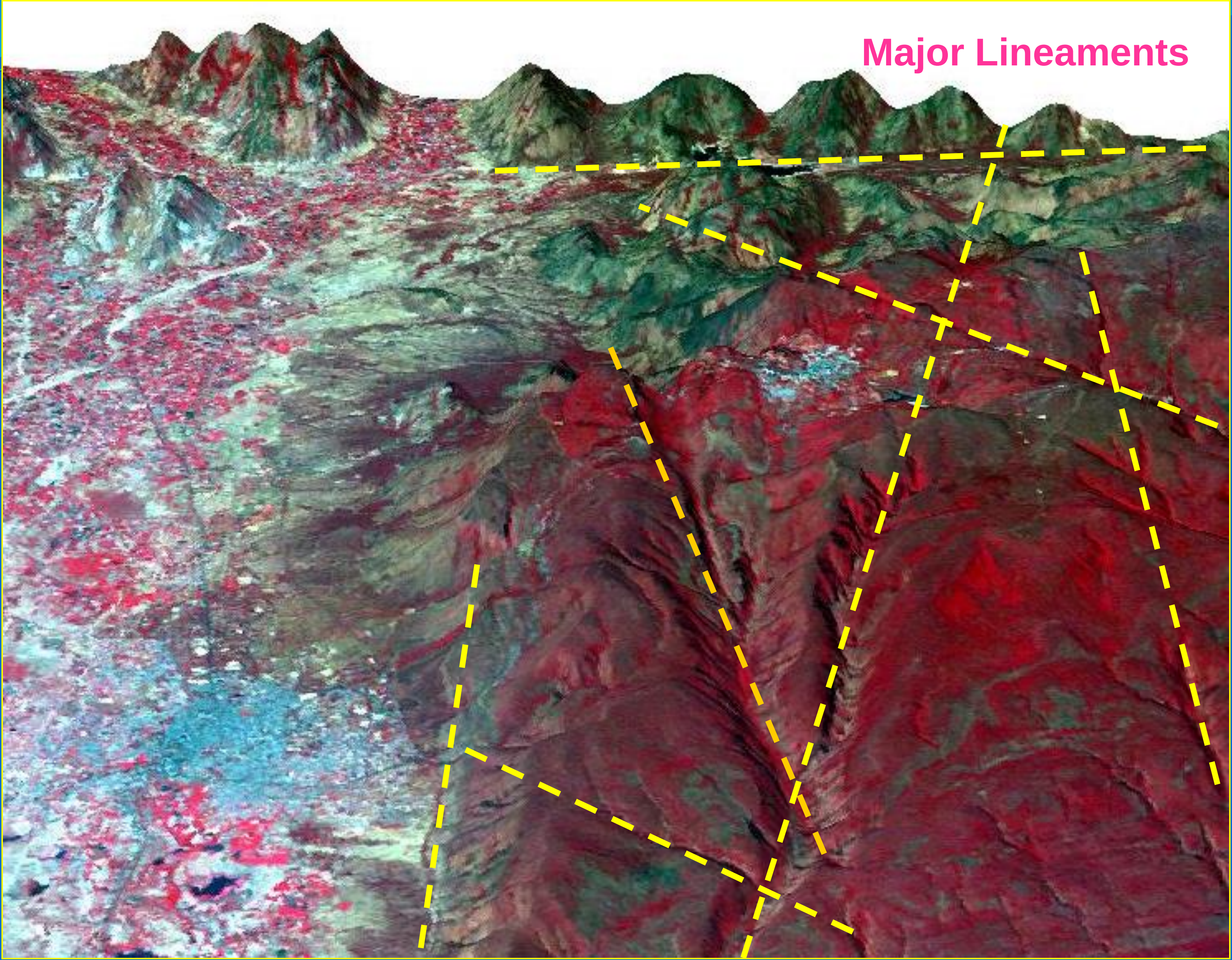
Pegmatite vein in granite boulder, Glenwood Canyon

boulder of granodiorite that includes a section of an aplite dike, showing the 3-dimensional nature of a dike. The dike can be seen on the backside of the boulder as well, giving the appearance of a layer of white sandwiched between two chunks of darker rock. (The black spots in the granodiorite are hornblende and biotite.)

Pegmatite is generally similar in composition to aplite but is very coarse-grained. Pegmatite may contain more accessory minerals than aplite. This photo of the planar surface of a pegmatite dike shows (in this case) the difference in color between potassium feldspar (pink) and plagioclase feldspar (white). The very light-gray mineral is quartz and the thin black lines are sheets of biotite (mica).



Dyke ridges (DR) occurring with the granitoid terrain in Kanker district, Chhattisgarh state. Dyke ridges most of the times can be easily identified from the satellite image due to their good contrast from the background litho units as well as their shape/form and mode of occurrence.


Major Lineaments