Remote Sensing in Hydrogeology

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Introduction

Earth From Space

Remote Sensing in Hydrogeology

Surface Water Sources

- Rain, snow and springs.
- Glaciers are storehouses of ice and snow.
- The snow begins to melt when temperatures rise giving running water forming streams.

Glacier Melt Water

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- In the past sequential aerial photography helped monitor the to and fro movement of an ice front.

- Today, this is done with the help of satellite images.

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- The quantity of snow precipitated can be used as a measure of the amount of melted water that will be generated flowing further as streams.
- Earlier snow thickness was measured with the help of field methods. (Air Pillow attached to a Manometer).
- In recent times GPS units are being used to determine the thickness.

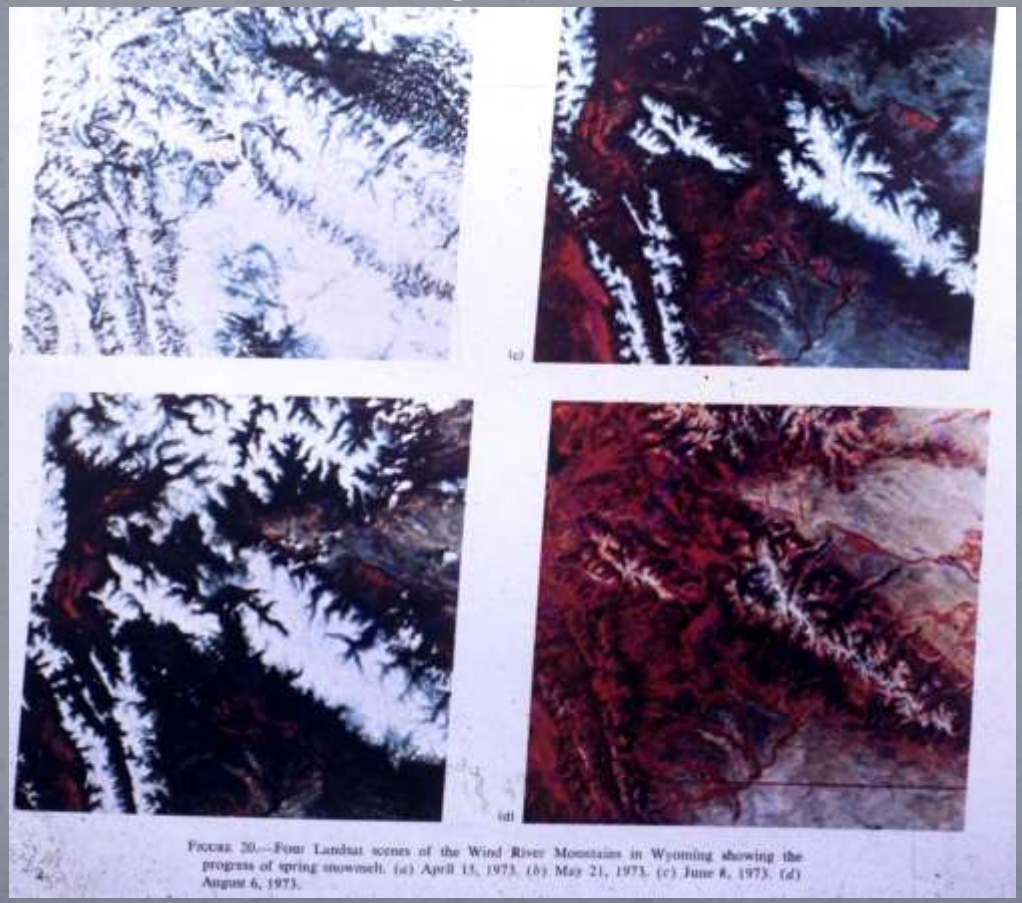
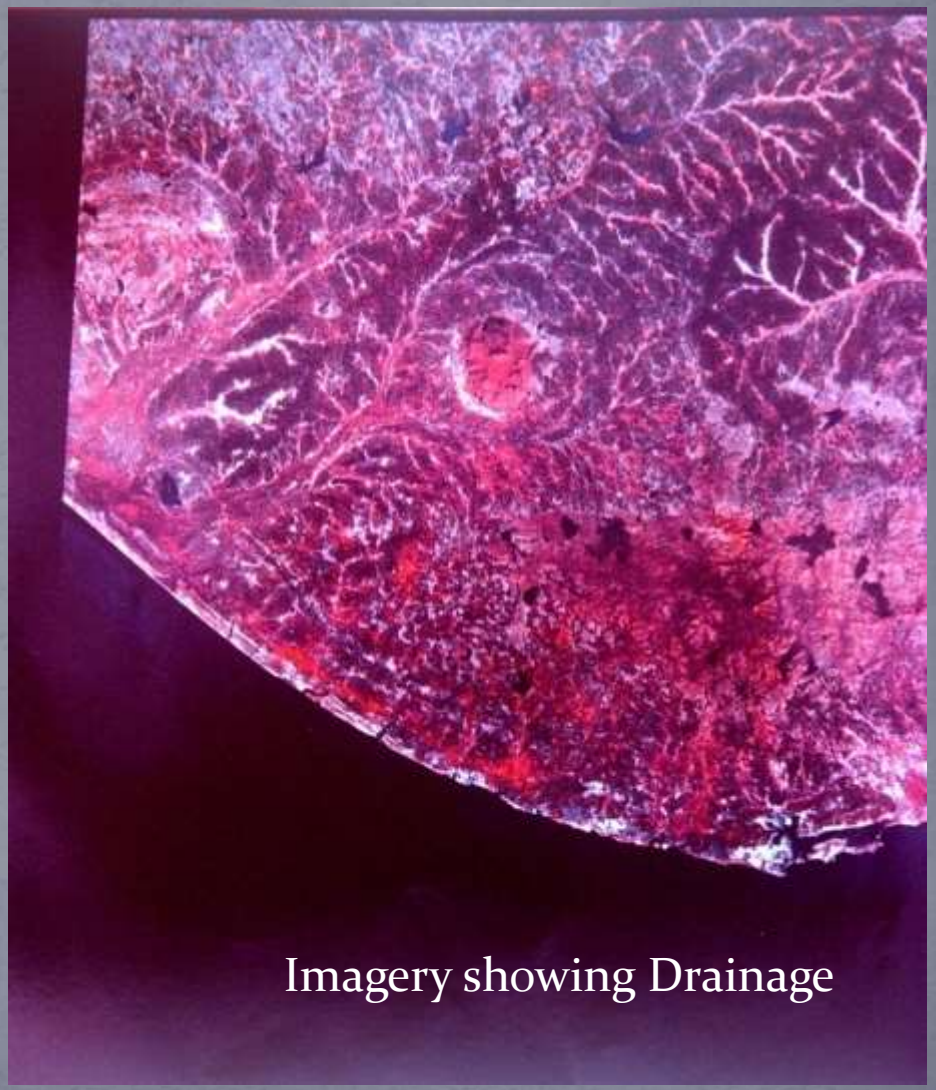


FIGURE 20.—Four Landsat scenes of the Wind River Mountains in Wyoming showing the progress of spring snowmelt. (a) April 15, 1973. (b) May 21, 1973. (c) June 8, 1973. (d) August 6, 1973.

Surface Interaction

- Rain water and melt water interact with ground surface in the following ways:
- ✓ Surface run-off.
- ✓ Percolation in the ground.
- ✓ Evapo-transpiration.

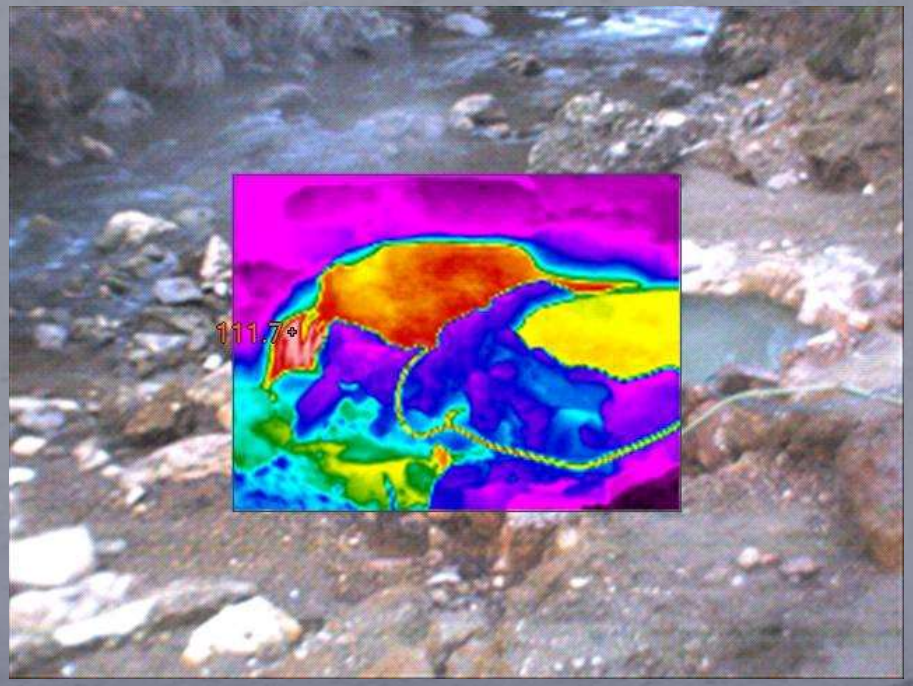
The first two factors depend on the **slope** and the **permeability** of the ground. Where higher the permeability of the ground surface, lesser the run-off and vice versa.



Imagery showing Drainage

Springs

- Springs can be detected due to vegetation on Black and White photographs or Near Infrared Imagery (Red Colour).
- In thermal Infrared springs are detected by cooler area around them.
- For example, Thermal imagery of the Ogden Hot water springs from Utah flowing into the river.
- http://activerain.com



Limestone terrain

- Absence of external drainage indicates a limestone terrain which is highly permeable.
- Limestone when underlain by shale results in a spring.
- Photo of Karstic terrain.
- http://rst.gsfc.nasa.gov

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Permeability

- Relative permeability of rocks can be studied by observing drainage density on aerospace imageries.
- Secondary permeability is caused due to fracture zones and other weak planes.

Figure 12-9. Stereogram of possible faults in an sands. (*Courtesy of U.S. Geological Survey.*)

Secondary Permeability generated by Fracturing

Alluvial Fans

- At knick points developing at junctions between mountainous terrain and alluvial planes at their foot. For example, Himalayas and Ganga-Yamuna plains.
- Streams loose their speed resulting into deposition of material brought by them. This results in fan shaped deposits called alluvial fans.

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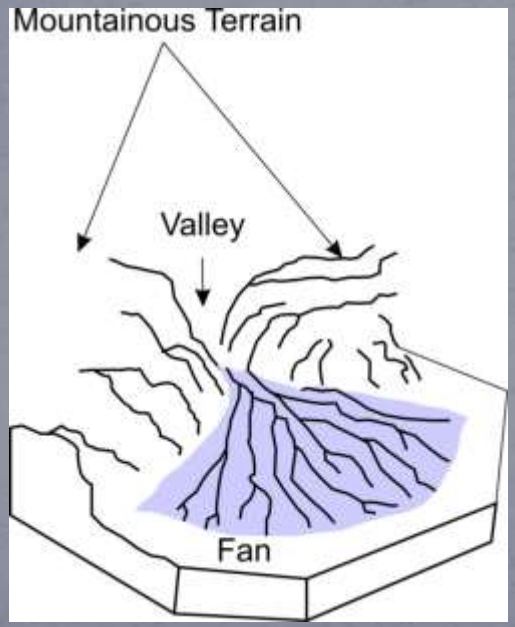
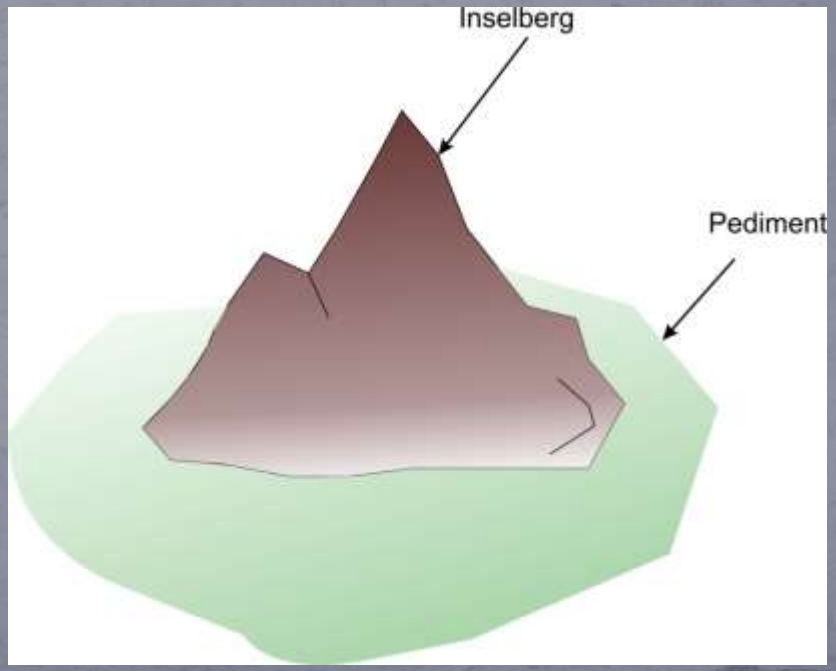
- The water entering at the top of the fan is distributed through multiple channels (dichotomy) and emerges in the form of springs at the base.
- Base of a fan shown shows a dark toned rim due to growth of vegetation and moisture giving rise to shallow groundwater conditions.
- www.buzzle .com
- Pediments surrounding inselbergs have similar groundwater conditions.





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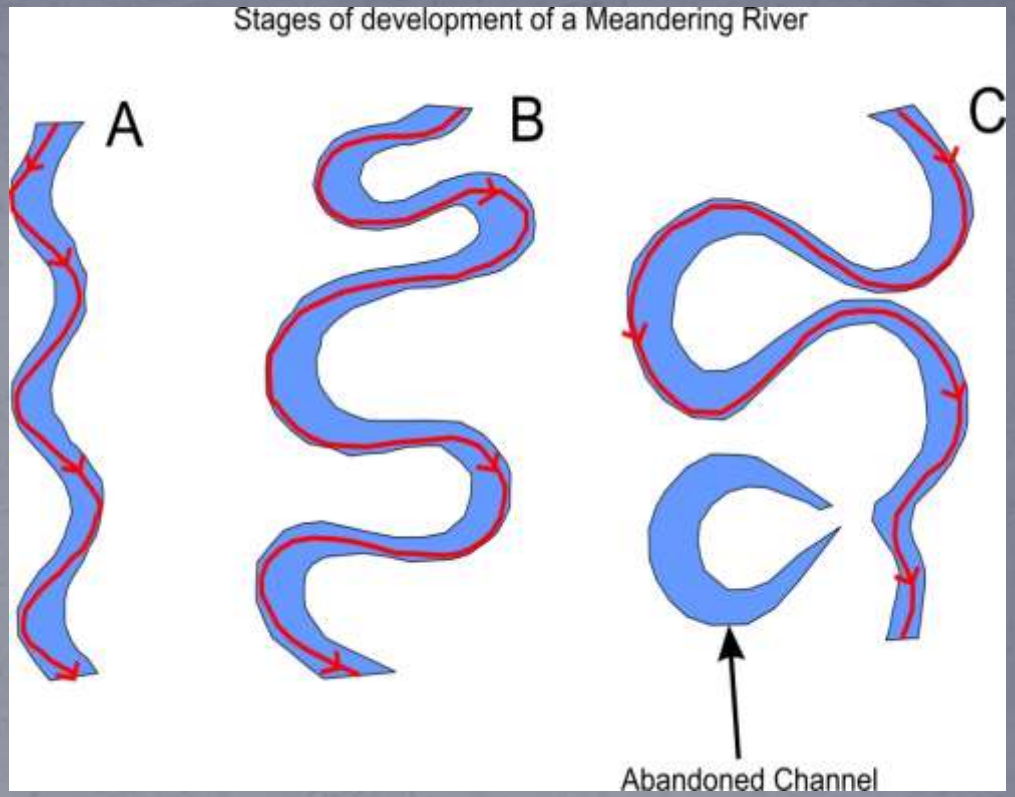
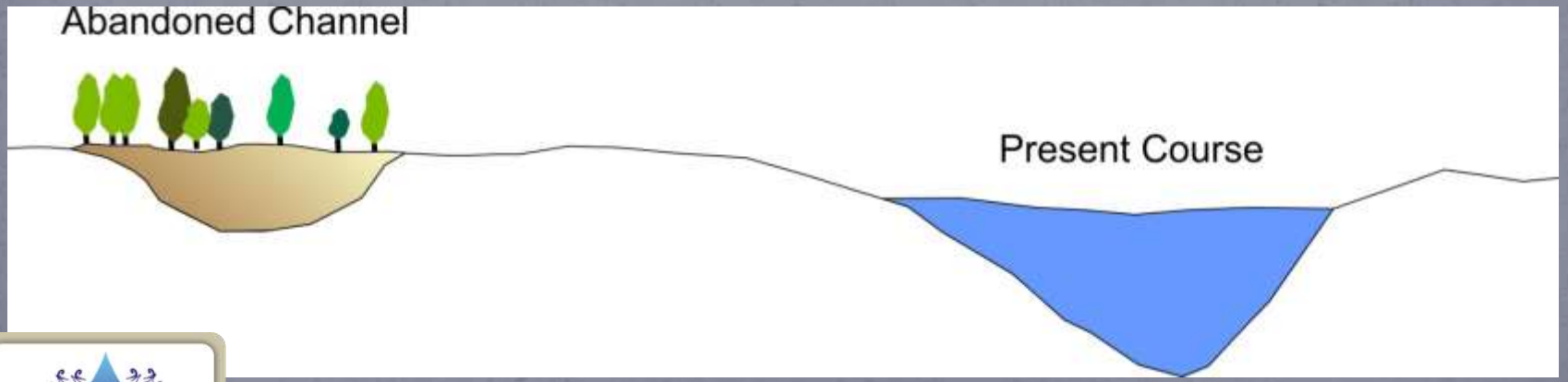
River Channels

- In flood plains a meandering river leaves a number of abandoned river channels behind them giving rise to an anastomotic drainage pattern.
- These abandoned channels are associated with coarser channel deposits. The spaces between them are capable of retaining water and often form sources of shallow groundwater.

- On aerospace imageries these channels are marked by water-loving vegetation like Elephant Grass and Casurina etc. For example, Indrayani river bed and Burhigandak flood plain.





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- When these abandoned river channels are covered by a subsequent cover, they have no field manifestation , however on images, their presence is clear due to field pattern and tone.
- Near Infrared and Thermal Infrared show these in darker tone due to their moisture content.

Fig. 3.12. Aerial photograph of the north coast of Java showing how density patterns of turbid water reflect the prevailing current pattern which, in turn, accounts for the coastal abrasion near the eddy; an example of "indirect" interpretation of dynamics; the extinct old volcano occurring inland is subject to "direct" interpretation on a basis of its (static) form characteristics

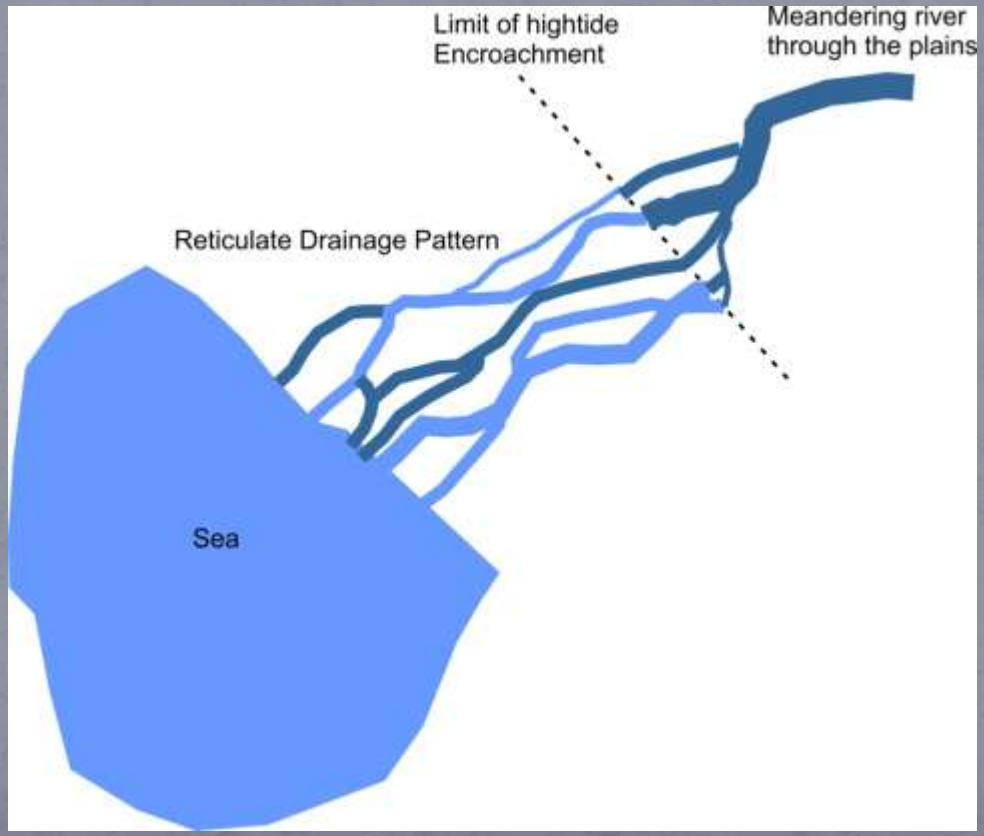
Fig. 3.13 Aerial photograph of part of the lowlands of northern Java, Indonesia, showing how "associated features" such as villages, termite hills, etc. mark a natural levee by means of density recordings

Salt Domes Anomalous Drainage

Figure 12-3. Mosaic of a circular topographic high, directly underlain by a salt dome. The surrounding area is a lowland coastal swamp. (*By permission from Edgar Tobin Aerial*

Reticulate Drainage Pattern

- Reticulate drainage pattern indicates such areas where tributaries rejoin main stream upwards due to the force of the tide. (Padma River)



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Salt Domes – Satellite Image

Lineaments

- On black and white aerial photographs, fracture zones appear as dark-toned lineaments against light toned dry grass.
- The dark tone is due to selective growth of vegetation along them. Fractured rocks when associated with moisture support vegetation.
- This is because fractures at times function as channel ways facilitating movement of groundwater.

Lineaments

- For example, the most prolific wells in Lonavla city are situated along such fracture zones. (Illustration – Lonavla Aerial Photograph)


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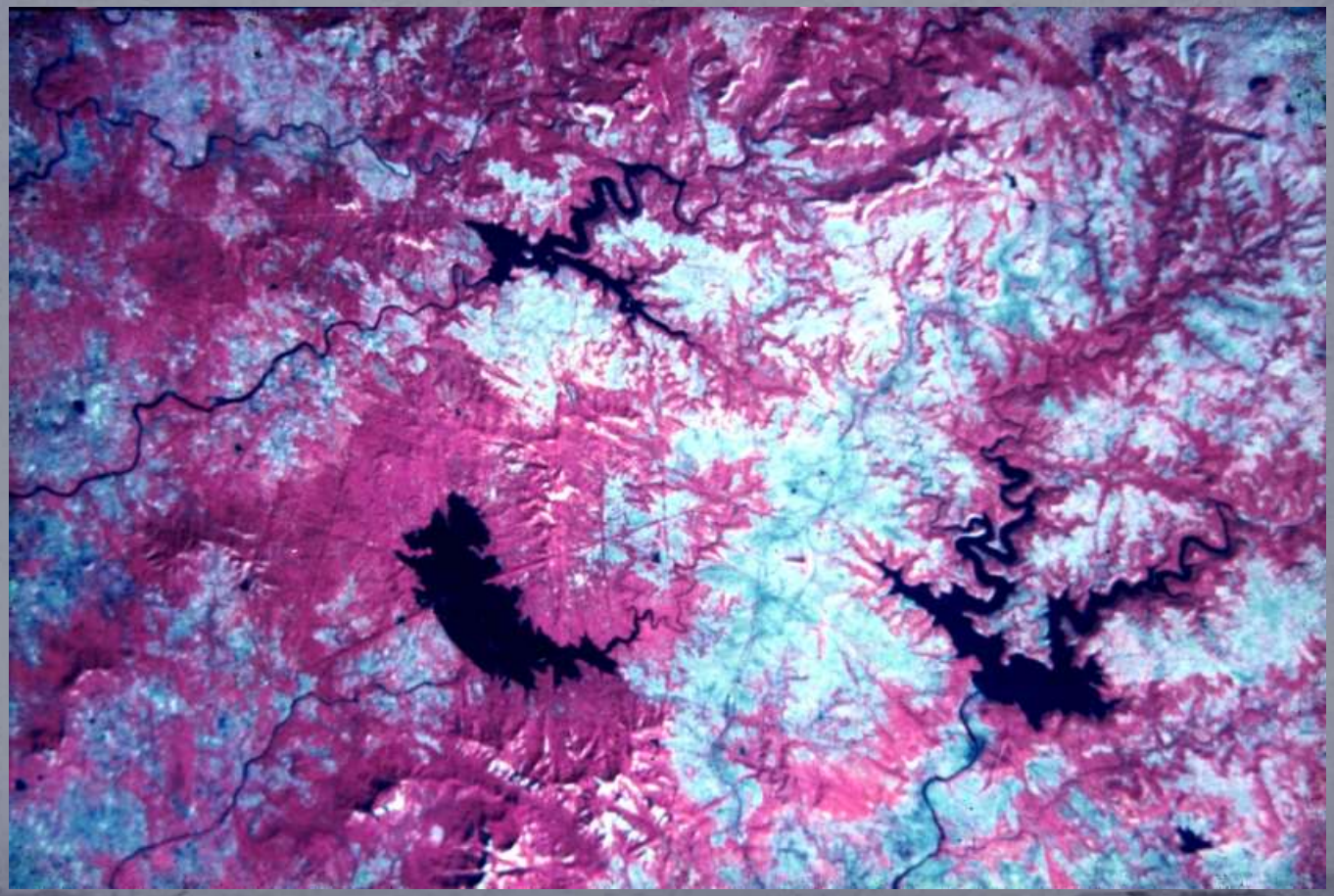
Lineaments

- On False Colour Composite (FCC) satellite images, fractures appear as red lines against a yellow-blue-white background.



Dykes

- Broad dykes are impervious and function as barriers for groundwater movement.
- A dyke parallel to a slope may impound groundwater locally.
- Narrow dykes are riddled with cooling joints especially along the margins. The joints are open and may store some water.
- For example, near Kusgaon, Southeast of Lonavla, wells situated on the dyke have a higher yield and more sustainability as compared to wells in the host rock.

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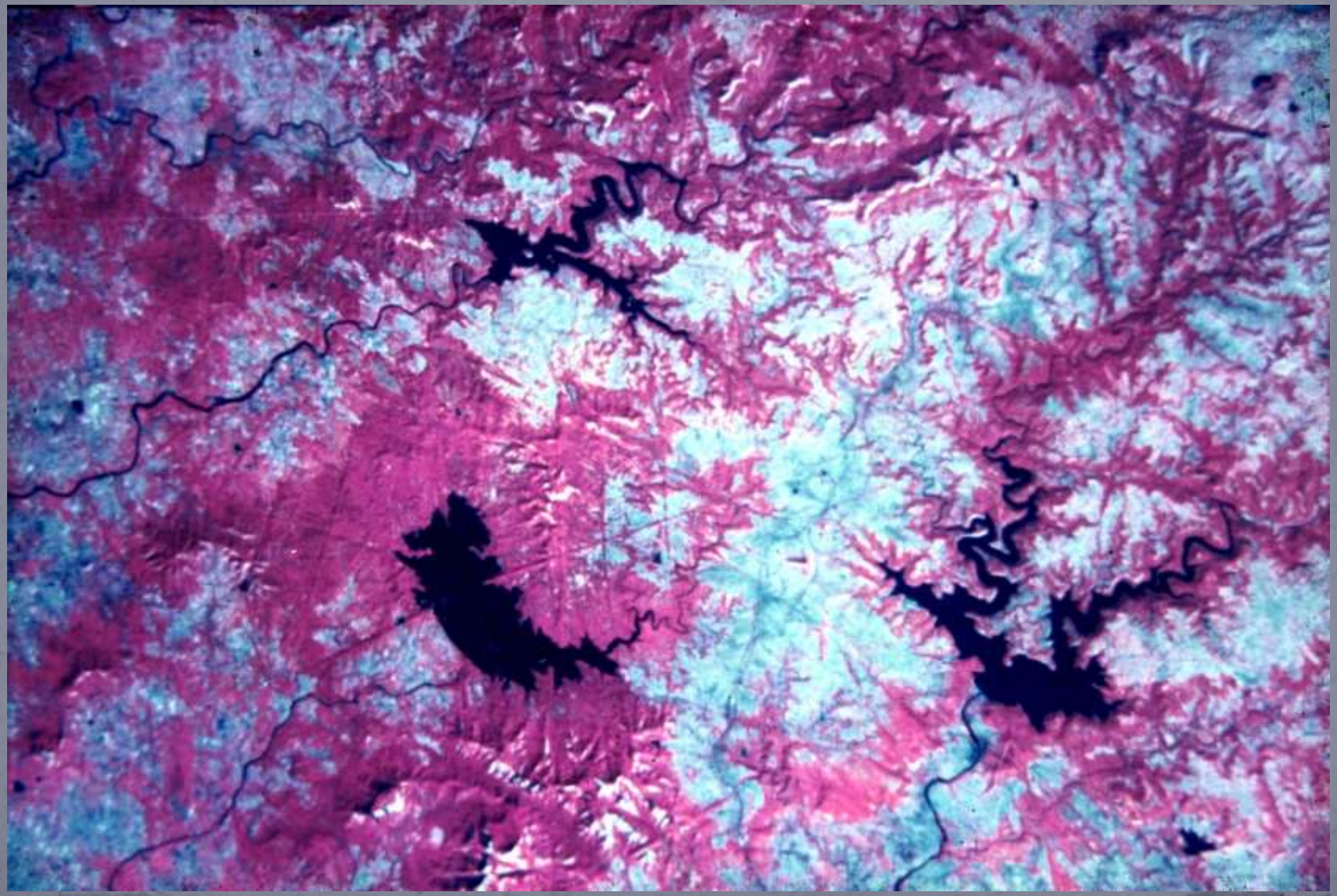
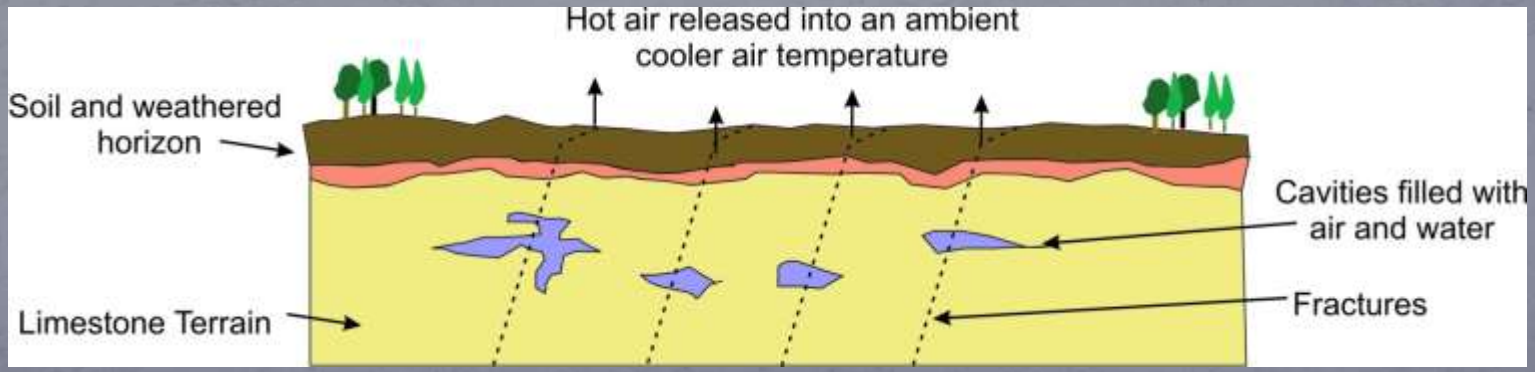
- False color images highlight dykes as red lines due to the vegetation growing on them.



Thermal Infra-red Imagery

- Thermal Infra-red range can detect warmer areas.
- For example, the Karstic terrain to the South of France is underlain by solution cavities hosting warmer air in contrast with cooler atmospheric temperatures of winter. The fractures are then highlighted by the warmer air escaping through them. They appear as white lines surrounded by a darker background.
- These fractures are covered by soil and hence would not appear on panchromatic Black and White Aerial Photographs.



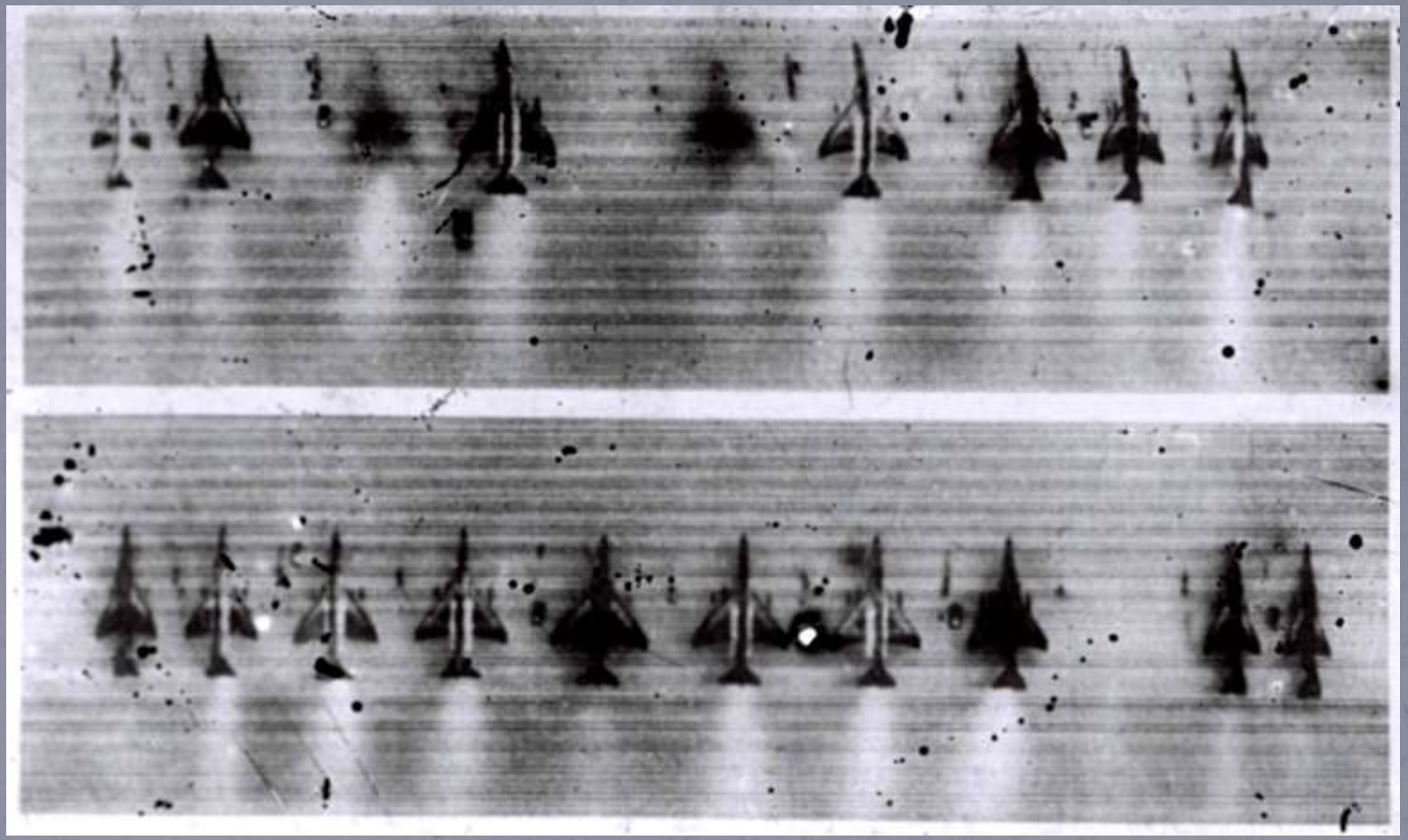


IMAGE.

Water Pollution

- Silting of reservoirs can be easily detected by using short Visible radiation (0.4-0.5) which has a higher penetration.
- During high tide brackish water encroaches up on fresh estuary water and leaves the surrounding area a kharland.
- Dark tone in Visible and Near Infrared indicate such areas.
- For example, West Coast Amba river Estuary.

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Water Temperature

- A thermograph depicts temperature variation. Polluted warm water entering a river is shown with a lighter colour than cold unpolluted water.
- For example in the image below, Thermography is being used to detect the presence of water in building foundations.
- http://www.advancedrestoration.com

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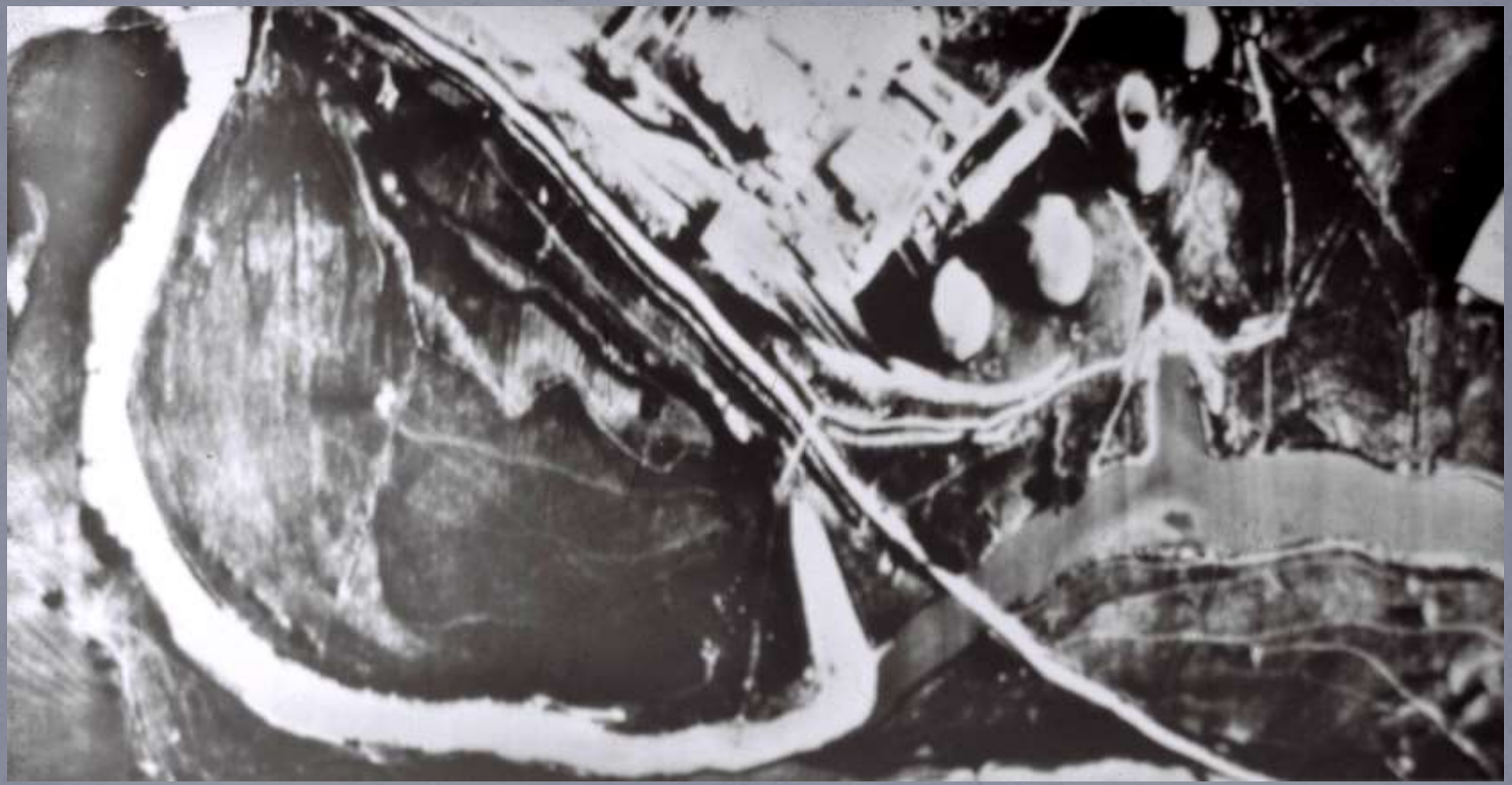
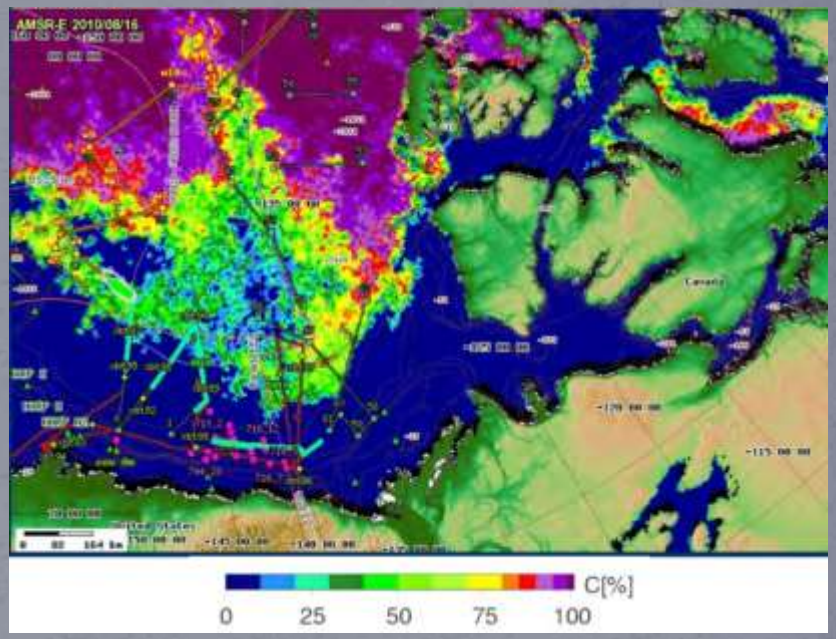


Microwave Radiations

- Microwave Radiations can penetrate through loose soil and colluvium.
- Underlying features like buried river channels can be detected.
- Concealed faults can be detected on Remote Sensing images due to moisture hosted by them.
- For example, the Microwave imagery below taken from USGS shows Sea Ice Concentration.



Limitation

- Though structures like Faults and Fractures responsible for recharge can be studied, deeper aquifers cannot be detected by Remote Sensing methods since most of the wavelengths do not penetrate the ground.
- The permeability of rocks can be interpreted through satellite imagery and highly permeable rock strata may recharge underlying areas.

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Some Interesting Images

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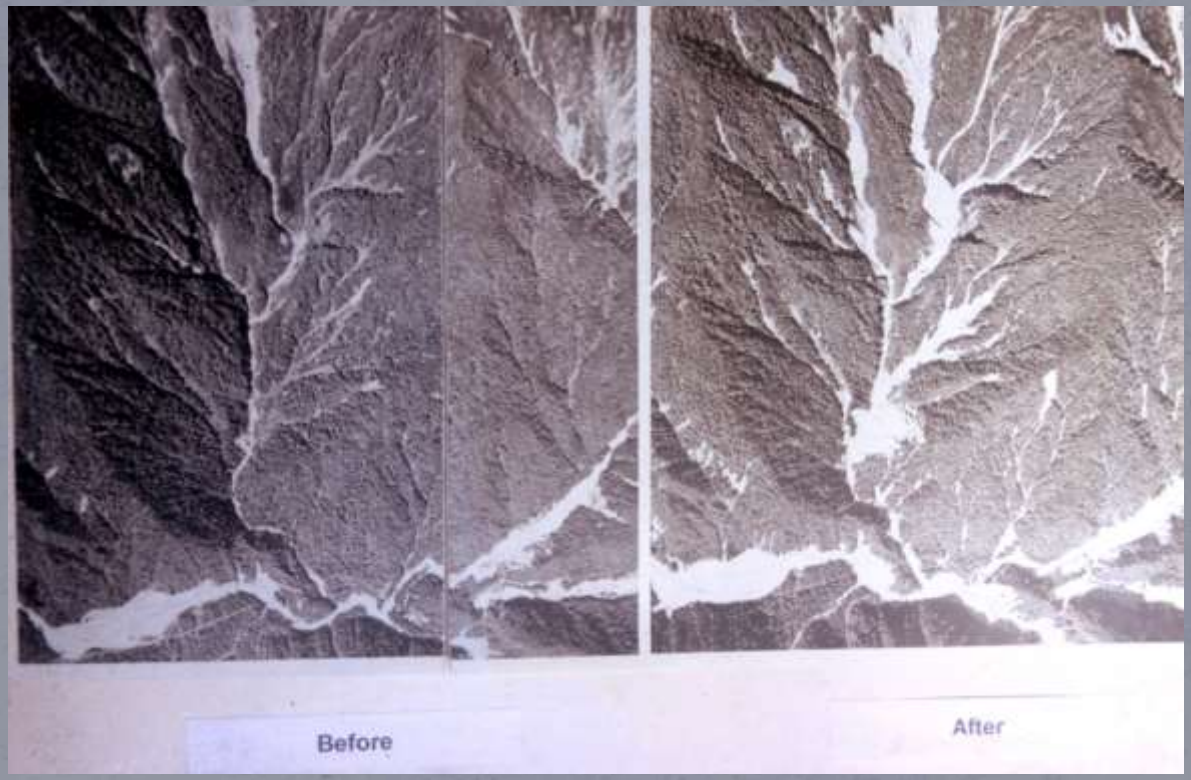
Volcanic Vent

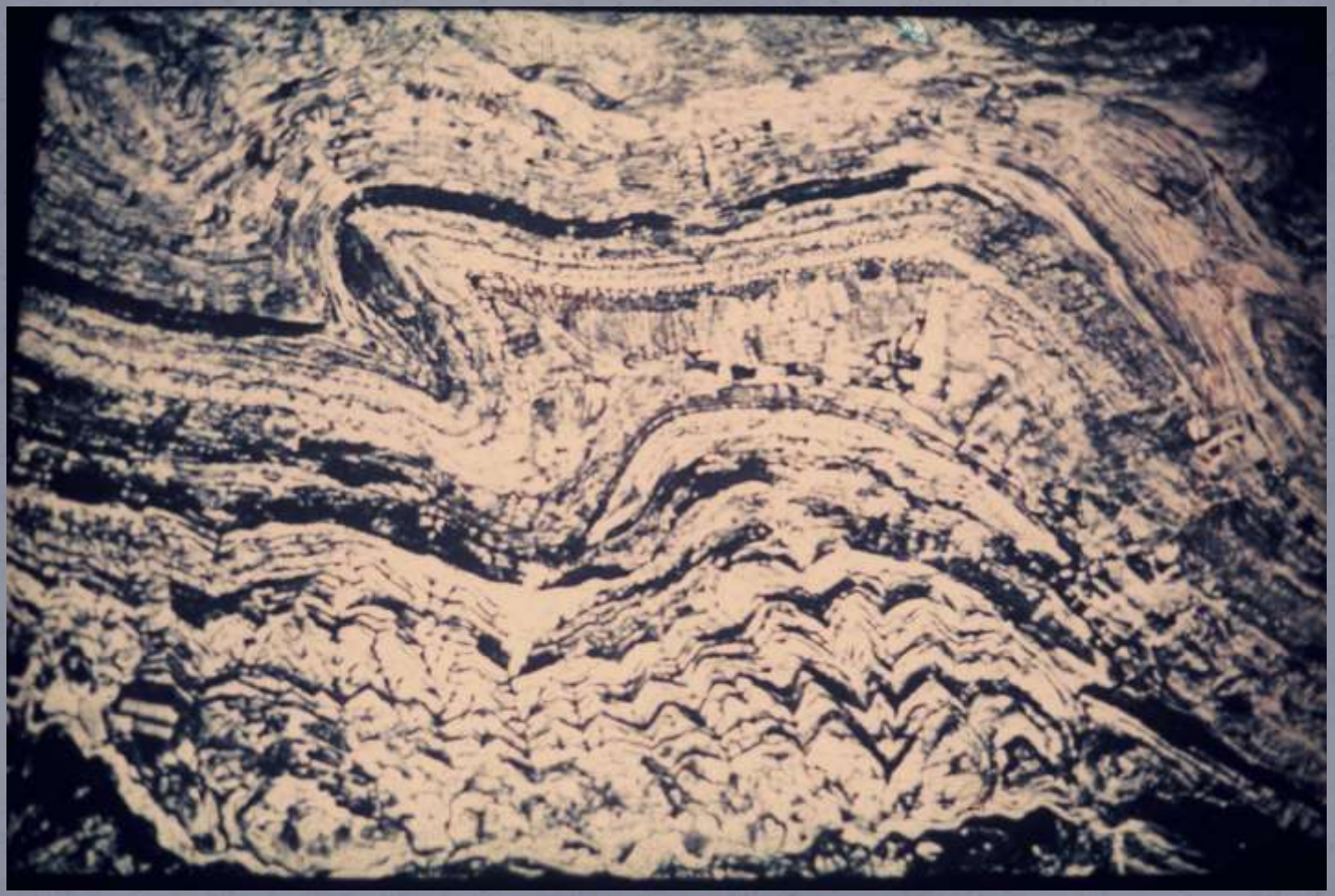
Figure 9-3. Stereo triplet of cinder cones and lava fl
dipping strata. Four-lens photographs. (*Courtesy of*
Conservation Service.)

Landslide- Before and After

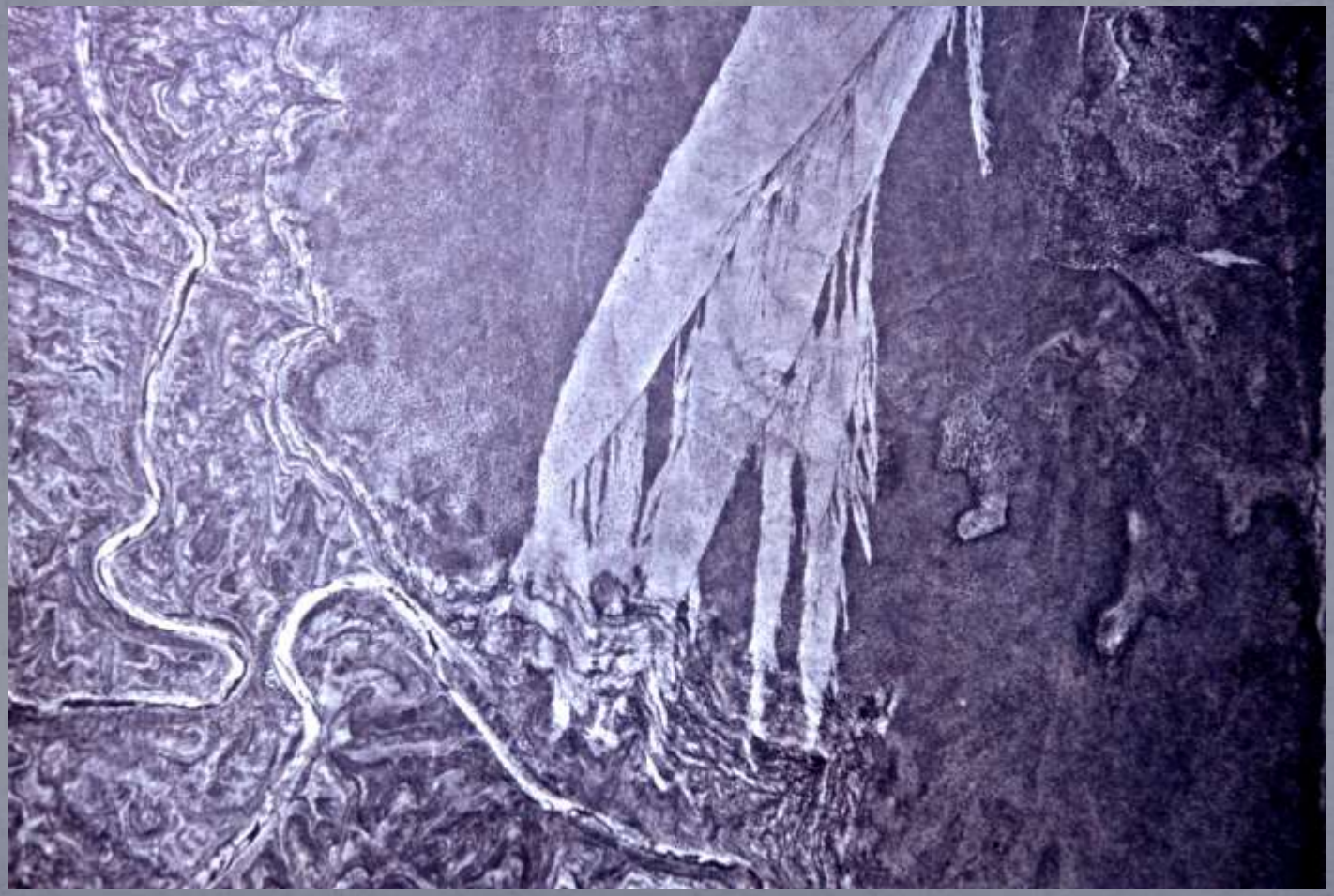


Ear of China

Folding Satellite Image



Forrest Fire – Aerial Photograph



Time the Fourth Dimension

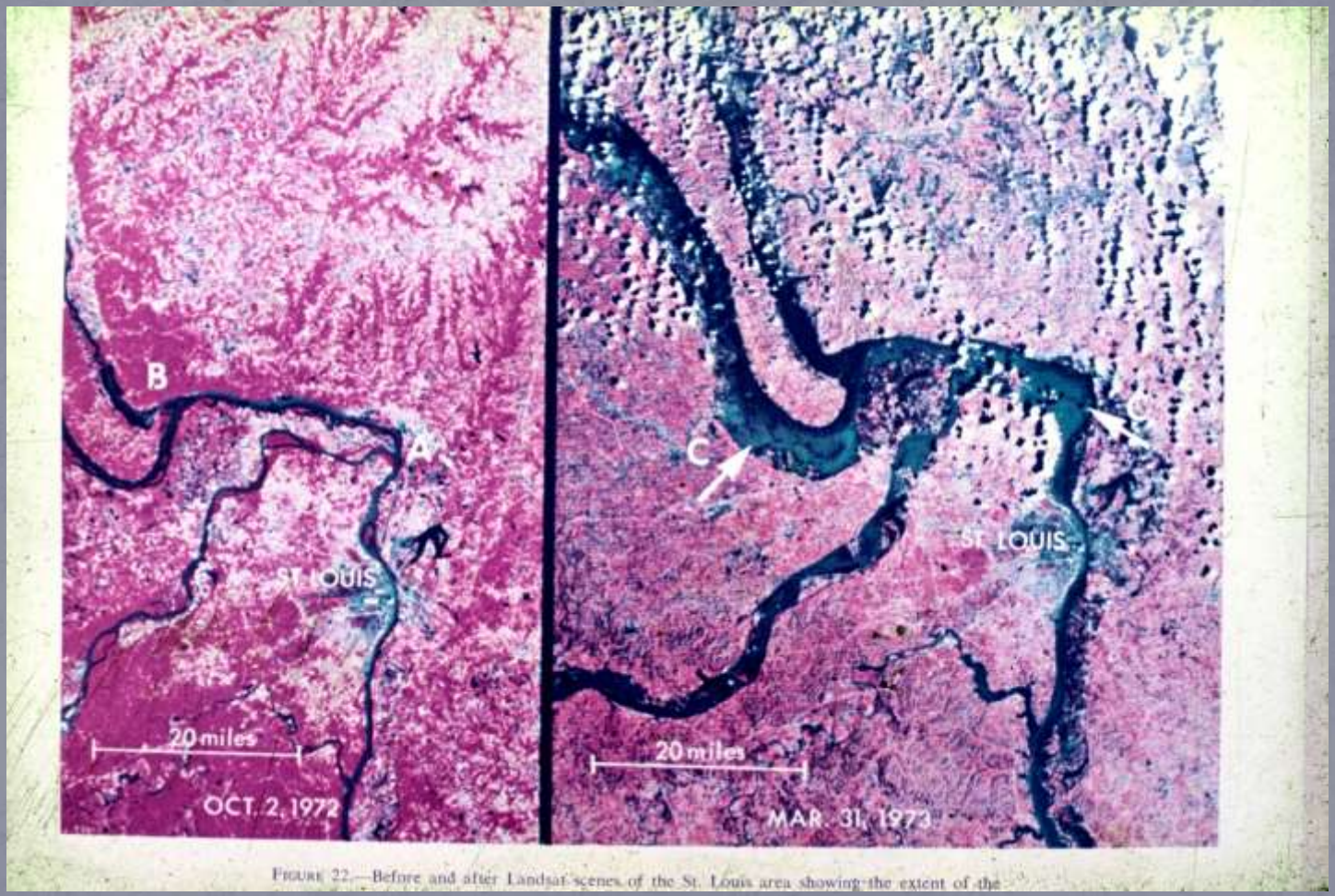


FIGURE 22.—Before and after Landsat scenes of the St. Louis area showing the extent of the

Infrared Imagery

Thank You…