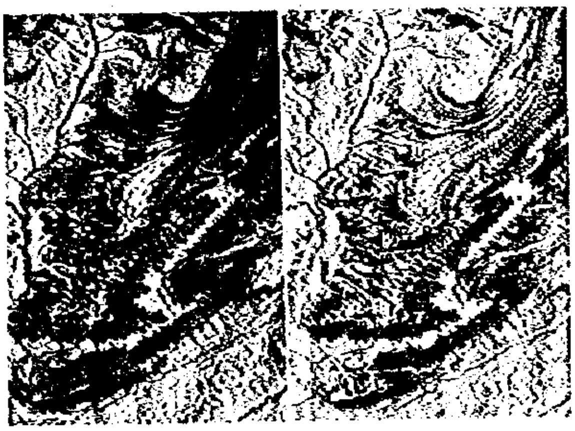
Boundary (Contact)

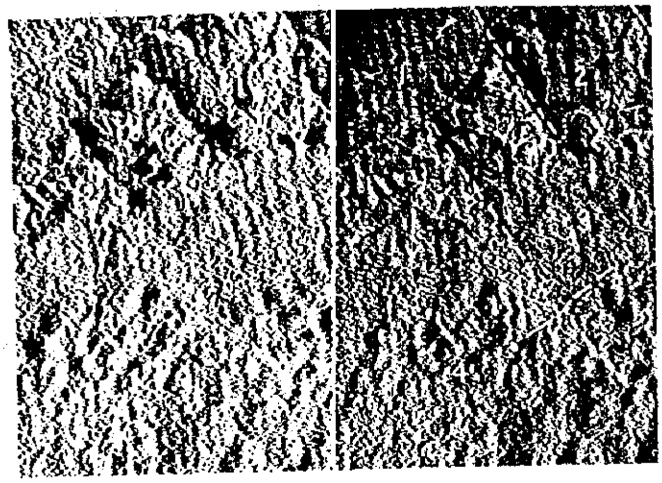
Following beds and plotting boundaries of hard beds, drainage pattern and tonality in an arid climate



The 13 lithologic units are arbitary chosen. Most outstanding and to be chosen for a keybed is 6. It is a very light-toned calcareous shale, wedging out at Y. Note the small close spaced gullies at right center. 1,5,9,13 are sandstones indicated by scarps. Darkest is 5 (red brown sandstones with thin sandy shales). At 3 is alluvium. Arrows indicate direction of dip. At X, dark sandstone 5 is down-thrown. Bed 11 has two sandstones S_1 and S_2 ; S_1 wedges out. Identity of chosen units, formation contacts and fault indications should be field controlled. (Big Horn Mountains, Wyoming)

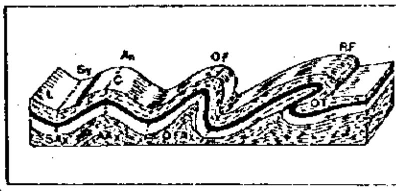
Jointing (Diaclasa)

Limestone of different composition



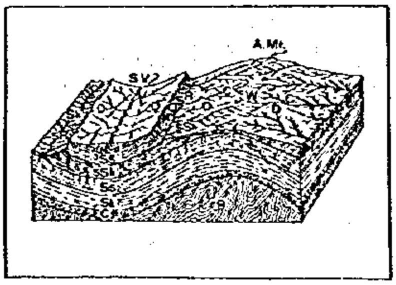
The lower Tertiary Borelis limestone (3) is a cherty, dense rock underlain by Upper and Lower Miocene sandstone (1,2). The siliceous Borelis limestone resembles sandstone in its morphologic appearance (1), but has poorer vegetation. Limestone (4) is the Klasafet Formation, an uplifted Pleistocene coral terrace. It has a nearly horizontal attitude and lies unconformally on 3, which is tilted (arrows). The Klasafet limestone shows pinacled surface on tropical Karst. (Vogelkop, Hollands New Guinea)

Types of folds (*Tipos de Plegados*)



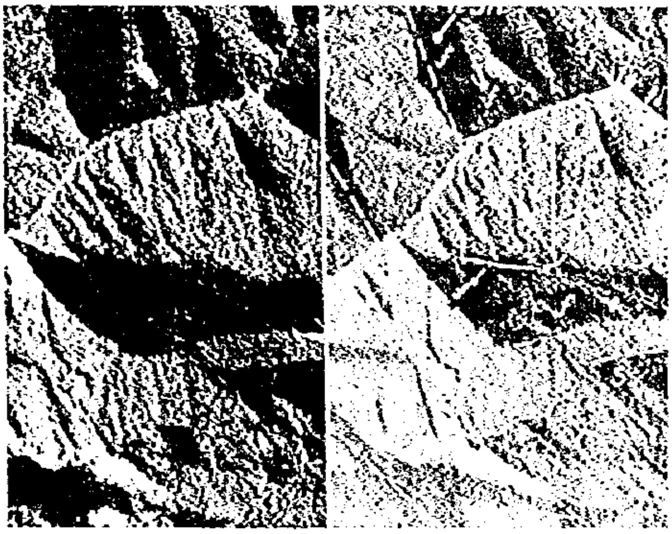
The type depends on the intensity of tectonic pressure. An is an anticline, with crest C and anticlinal axis, AAx. The two slopes are called limbs or flanks (L). The syncline (Sy) and its axis (SAx) indicate that the structure is symmetric. When the axial plane (O-FAx) is tilted, an assymetric or overfold, will result (OF). Continuous tectonic pressure will result in a recumbent or overturned fold (RF). This fold is usually connected with an overthrust (O-T) fault. Recumbent folds may become covers or nappes in intensively folded mountanaous areas.

Block diagram of an anticlinal mountain and a synclinal valley.



The anticline (A.Mt) forms a ridge. A thick sandstone bed (Ss2) is overlain by a sandy shale (sSh). Consequent drainage C of sandy shale character forms dipslopes (D) which however do not conform with Ss2 below. The watershed W, however, follows the axis of the structure. The synclinal valley (S.V.) is formed by sandstone Ss1. It forms a through with dipslopes (D) and alluvial fill (A). The shale at the left shows a strike controlled strato subsequent river (sR). At the center, stream sR follows the scarp in a similar sense. The tributaries from the anticline are resequent streams ; the steep short gullies from the scarp obsequents (O). Cgl is a base conglomerate ; B is base rock.

Faulting, faceting and dipsloping.



A sandstone formation Ss makes contact with a homogeneous tuff-shale formation (T-Sh). Dipslopes (arrows) show uniform character, similar shape, inclination and direction of dip. The facets (f) developed along fault planes are different in shape, inclination, and direction of the sloping. Ladle-shaped symbols mark direction of fault plane tilt.
At X are dipslopes of a sandstone bed overlain by shale. (Carpathian Mountains)

Folding

Landform

Hills

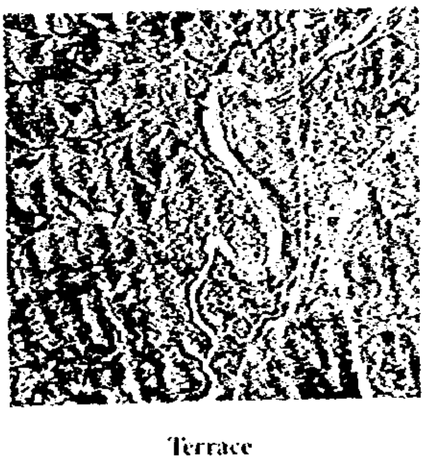
Landform

Landform

Urbanized Area Tokyo, Japan

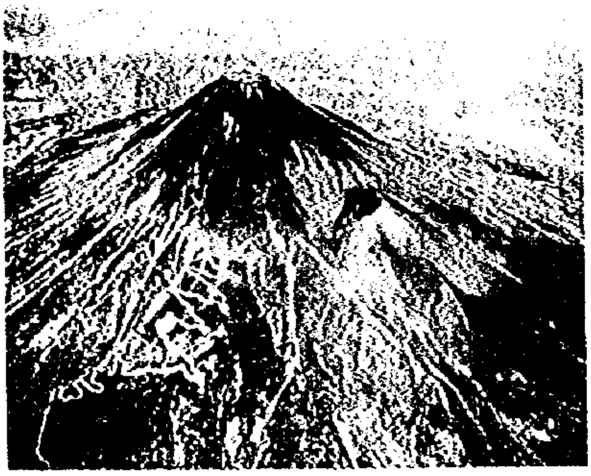
Landform

Mountainous Area



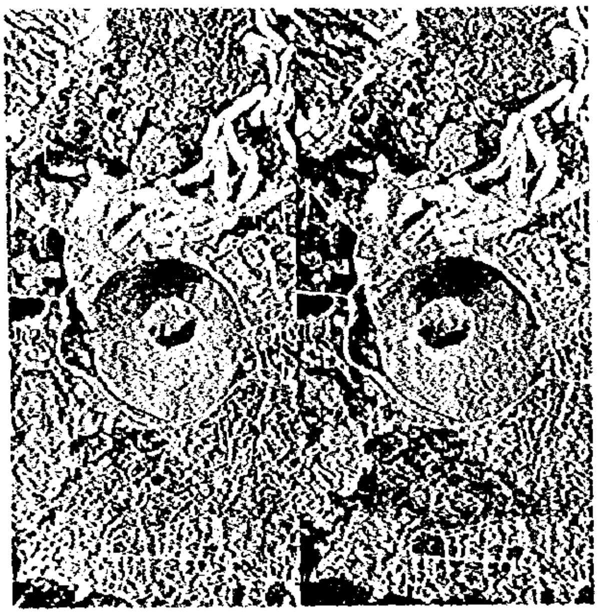
Terrace

Landform



Stratovolcano, Mts. Fuji, Japan

Landform



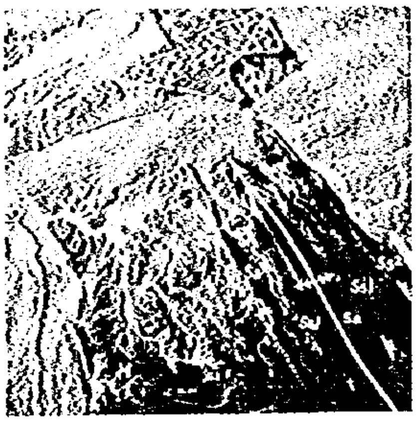
Monogenetic Pyroclastic Cone

Landform

Rock Glacier , Nepal

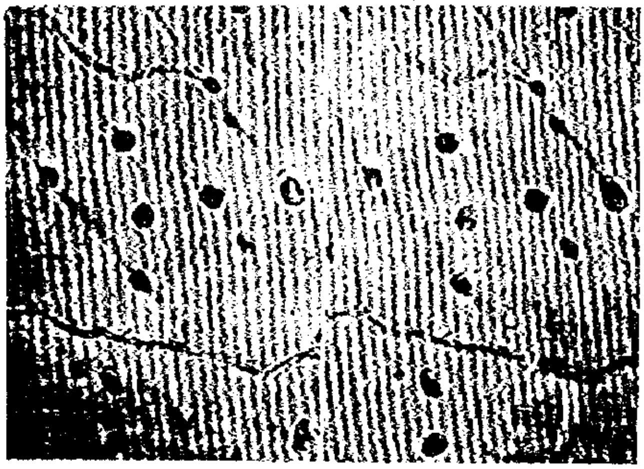
Probale lithology

Oblique view of a faulted structure with steep attitudes



The Sc sandstone in the core is dark brown and shows as dark elongated smooth ridges without surface drainage. Ss1 wedges out somewhat along the right flank. Greater distance of Ss2 from axial part indicates assymetry. Sh is a shale area well recognizable by its dendritic drainage. Sd is shift or losse sand which shows always in a light tone in arid areas like this. R, R1 are strike controlled braided river beds, sandfilled, with some scanty vegetation. At A is a granular alluvial fill similar to R1. Rather strong faulting by F-F has displaced the axis of the structure. F3 and F form a cross graben ; F2 an oblique fault ; Af an alluvial fan. (North Africa, Sahara)

Alignment of sinkholes

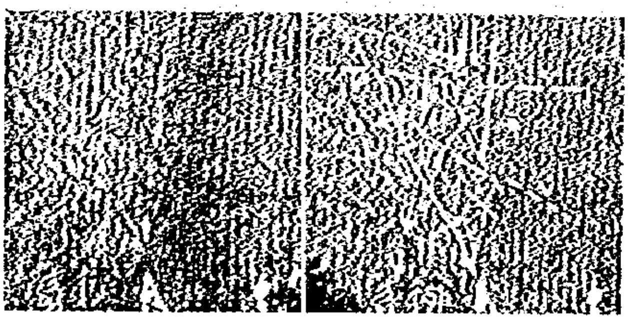


The relation between faulting or jointing and sinkhole forming is visible. Slightly darker lines are dissolved cracks in this horizontal limestone table. The straight wadi (V) is fracture-controlled. Sinkholes (X-X) are at cross-point of dislocation lines. Dark spots in sinks are vegetations. (Chott el Chergui, North Africa)

Schists in arid climate

The schist (Sc) has a dark tone and steep attitude. The banding is well developed and visible on this oblique photograph. The apparent foliation, however, is mainly due to sand filled low depressions and trenches between more resistant ridges. In beds with such steep attitudes, faulting becomes indistinctive. Discontinuity of this schist belt discloses the fault pattern. At X oblique faults (Fo) are cut by longitudinal fault (F). Longitudinal fault (F) disclose obliques (Fo) which are the older. S-S is sand. (Nafud Dahi, Arabia)

On an area in a rainforest, trees of different height and type indicate a plunging anticline

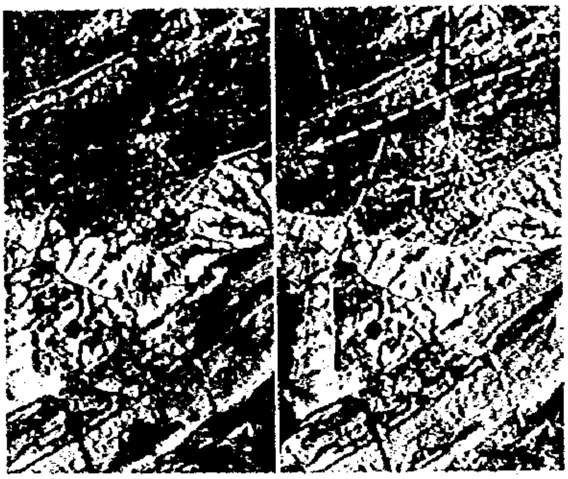


The core of the structure supports a lower tree growth with lighter canopies than the surrounding lowland.

At the flanks and on the plain, trees are higher and darker. Along lines Y-Y which are fracture lines, trees are highest with darkest canopies. In spite of dense plant cover, details of structure can be plotted (arrows). Fault tectonics and hard formations can be followed.

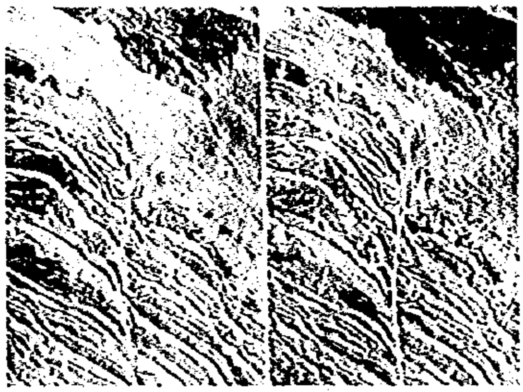
Even a lithologic conclusion can be made at Sh, where dendritic drainage pattern indicate a shale. At right bottom are cultivated clearings. (Mara District, Venezuela)

Alignment of vegetation on a gravel sand terrace (T,T^1) shows structural conditions of the underground



The calcareous Niobrara Formation at the lower half of the stereo, is indicated by infiltration hole rows (Skr) at the bottom. The strike of beds shows through the gravel terrace. Sinkhole (sk) on (T) is indicative for calcareous formation. Under T^1, a sandstone-shale formation causes alignment of sage brush and grass. The lighter low vegetation thrives on sandy ground; the darker on clayey ground. Note keybed at X-X. At Y, beds show banding and arching. The anticlinal axis is tentative. (Sheep Mountain, Jackson Cy., Colorado)

Dip Faulted Sandstone Shale Complex

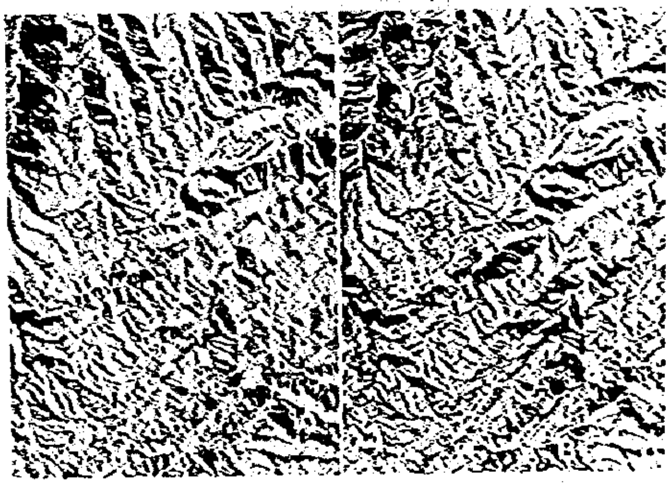


Since dipslopes with low grade attitudes show cross or transversal faulting more distinctly than steeper ones, displacement of beds a,b,c along watergap W can be readily seen. Faultplane cuts the flank (indented line) of an anticline obliquely. At X-X direction of dip turns to the left. The upthrown block (U) is at the right part of the photograph, the downthrown (D) at the left. Arrows mark the dip direction of the sandstone beds. Af is an alluvial fan. Fault data are calculable from dip of beds and distances. (Southern Sahara)

Qurtzite, Quartzite schist in contact with granite.

Quartzite (Q) and quartzite schist (Sc) in contact with granite (Gr).
The light tone is indicative for metamorphics rich in silica. The thick quartzite (Q) is resistant and forms ridges. Sc is thinner bedded, has alternate mica schist and greenstones. The lakes are glacial. Alignment of vegetation is visible on Sc and is assosiated with the different composition of rock. On Q is a spotty tree vegetation and closed forest on Gr. (Park Range Colorado)

Types of schist in arid climate.

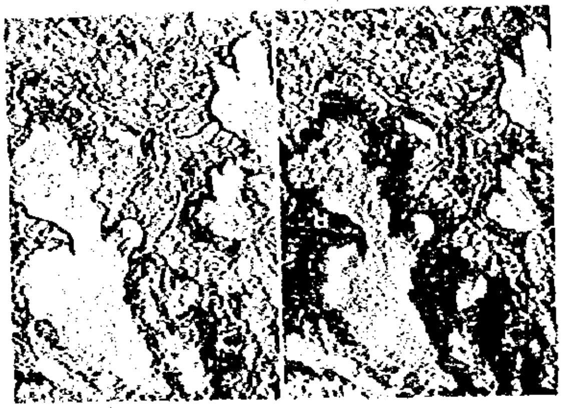


Three types can be distingushed. The phyllitic type is rather dark with a close-spaced drainage, indicating lamination at P. Ther is a gradual lateral transition at X between phyllites (mica schist) (P) and quartz schist (Q). Note difference of drainage pattern and forms between P and Q. At B are banded schists with light and dark gray bands.
They show the atittude of the schist complex. This is near vertical at B and about 40-50 degrees at B1. T is a remnant of an Pleistocene abrasion terrace with quartzite boulders laying on the surface. (Illescas Mountains, Sechura, North Peru)

Succession on Miocene andesite lavas and agglomerate in humid climate

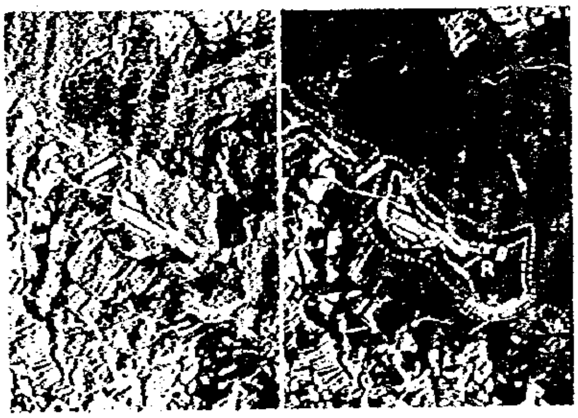
There are three lava sheets (Lv, Lv2 and Lv3) covering each other. No flow structures are visible because of advanced weathering.
Lv3 is the oldest, covered by a layer of agglomerates (bombs, lapillis, tuffs) marked with Agl. This is covered by Lv2 which is turn covered by the youngest Lv1. No surface drainage develops on the flows and agglomerates in spite of the tilted position of the beds. At Agl. a few infiltration centers can be seen, similar to sinkholes. The surface is uneven undulating on the lavas. Forest (Fo), few forest (Lf) and shrub (Sb) follow the aquifers. Lavas are covered by grass (Gr).(Transylvania Mountains)

Basalt flow in arid climate



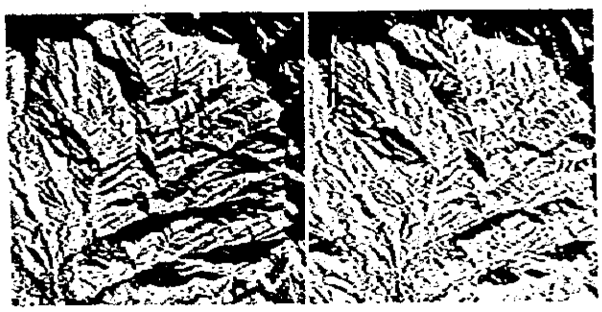
Three lava flows (1,2,3) coming from a nearby vent (near 3, bottom) show a basalt flow topography.
No surface drainage developed on the sheet. Rain seeps through coloumnar cracks and joints (cl). There are a few spotty infiltration centers (sp) similar to those found on fluvial terraces in arid climate. The older flows (1,2) are bleached on the surface due to weathering but the steep walls and the youngest flow 3 have a dark tone. Arrows shows the direction of the flows. The basalt sheet covers a near vertical schist complex. (New Mexico)

Ridge of dacite, an intermediate lava



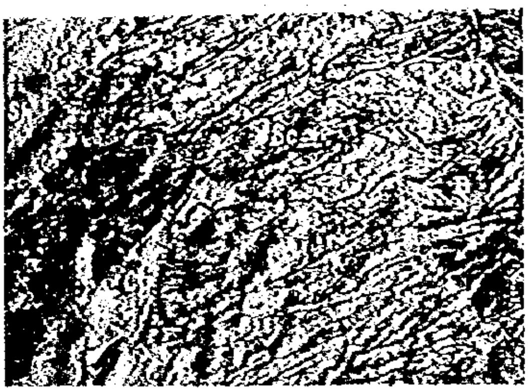
This light gray effusive contains quartz and much feldspar. R(the tone of the rock visible at X) forms a flat topped ridge with steep slopes. Surface drainage developed along fractures. This type of eruption is an example of a split eruption, through the rather tough lava did not form a cover like basalt often does. (Transylvania)

Semi-metamorphic Mesozoic andesitic tuff and agglomerate



This greenish gray lower Cretaceous extrusive underwent strong tectonic pressure, mainly fracturing. It resembles a schist with its intricate drainage. The general appearance is that of near vertical attitude.
Field observation showed that the tuff complex is near horizontal, indicated on the photo by boundary between coarse pyroclastics (*ffc*) and fine ones (*ffl*). (Rojada Mts. Sechura, Peru)

Basic igneous intrusive body with radial drainage pattern

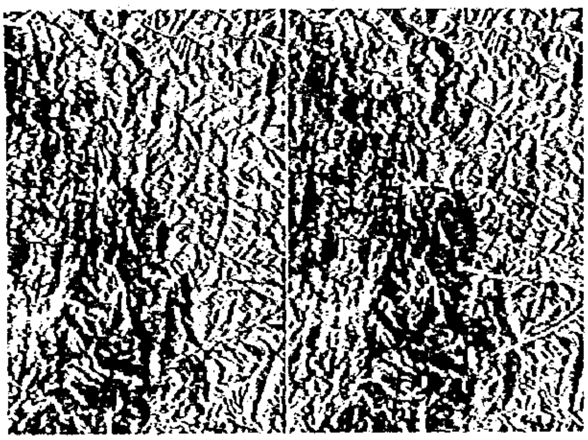


A basic igneous intrusive body at B. Radial drainage indicated by arrows. Surrounding schists (Sc) show subparallel to dendritic pattern along schistosity. Both are dark-toned, hence there is little contrast between Sc and B. F-F are fault controlled drainage lines. White spotted areas (X) are quartzite lag-blocks and gravels. Cg is a conglomeratic sandstone overlapping Sc. At Sh are soft shales and sands. (Sechura, Peru)

Biohermal type limestone interbedded in schists

Jurocretaceous reef limestone, locally called *mogotes*, this is a biohermal type interbedded in schists (Sc). The attitude of the lenticular limestone mass (L) is steep, near vertical. Sinkholes are oval shaped. At R is residual red clay. At Sl are slates. (Organos Mountains, West Cuba)

Contact between Granite and schist



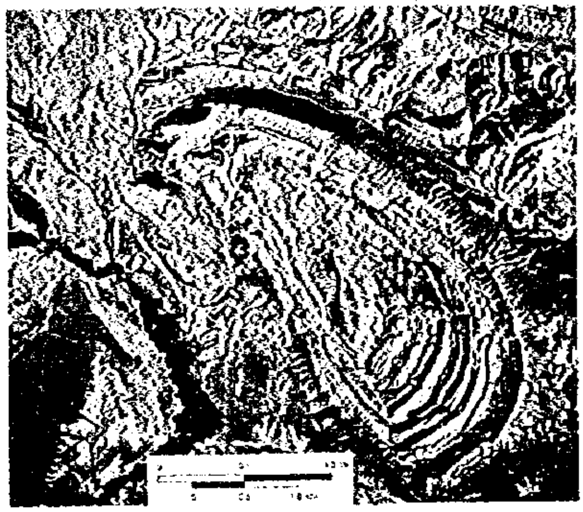
The Jurassic granite (Gr) has a lighter tone than the dark Carboniferous schist (Sc). The contact can be plotted along the tone difference. This results in outline of faulting along F-F. This abrupt change in contact outline interrupts the otherwise smooth curved boundary. The granite shows a tree-like drainage pattern with *pincers* at P-P. The principal fault controlled drainage lines are marked. At A-A are aplitic dikes in the schist. Foliation of the schist complex is at S-l. At X-X are quartzite inlays in the schist with a lighter tone. At T is an abrasion terrace with large quartzite blocks on the surface causing lighter tone. (Illescas Mountains, Sechura, Peru)

Folding (plege)

Anticline

Color Infrared NASA Airphoto of Milner Mountain, Colorado (North is at the top).

Anticline



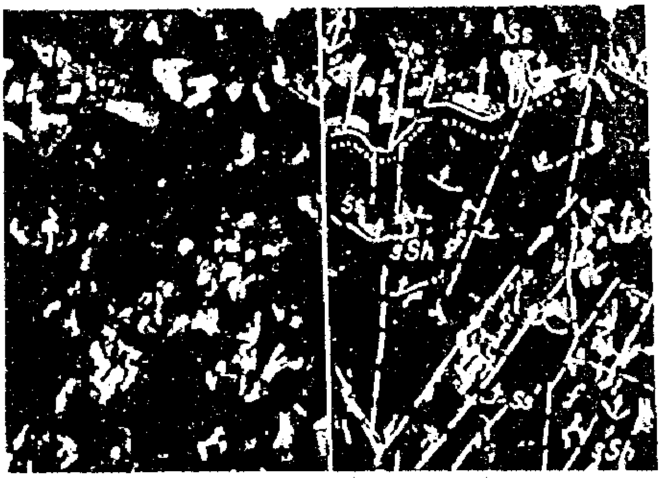
Circle Ridge Anticline, Wind river Basin, Wyoming. (North is at to of photo)

Anticline, Fault

Landsat Thematic Mapper Image over the Hodna Field Area, Algeria

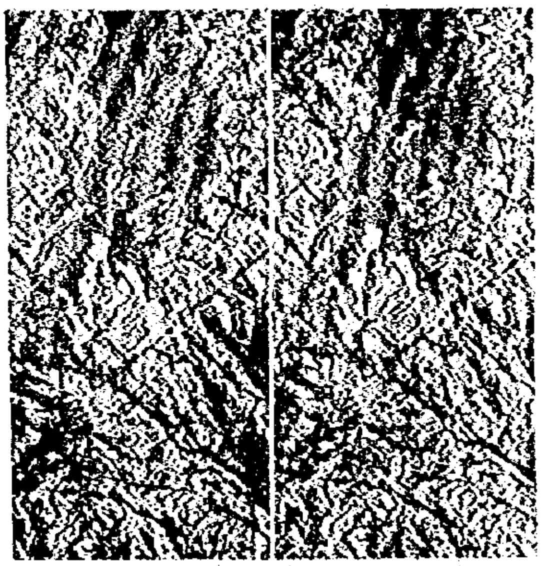
Fracture (Fractura)

Fault planes and facets in sandy shale area.



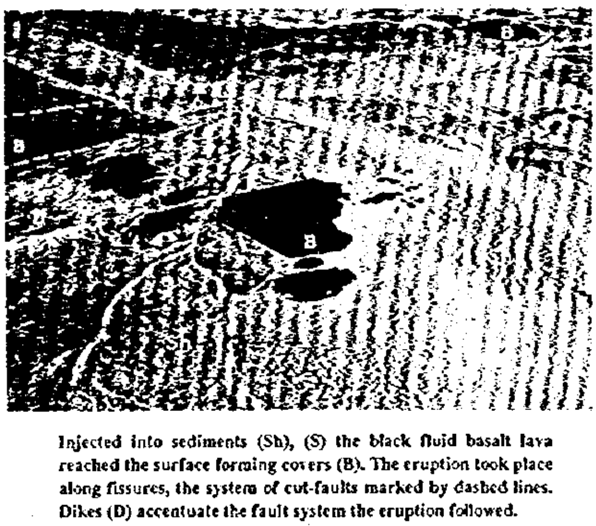
The oligocene sandy shale complex (sSh) has a few thin sandstone beds (Ssl), sufficient to evaluate the strike of the formation. The capping Miocene sandstone beds Ss form good dipslopes. The boundary indicates cross faulting which extends into the shales. At f-f, long, rathr even slopes developed. They have differnt inclination and direction.
The opposite sides of the fault-controlled valleys are deeper incised than the facets (f) which are not yet eroded deeply. (Transylvania)

Fractured granite mass with radial drainage



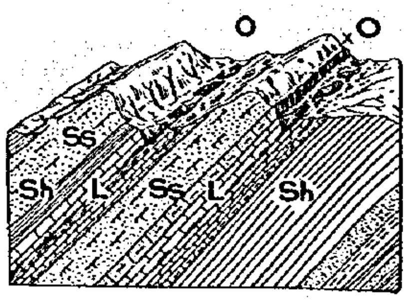
The Shermon Granite of Colorado shows a generally radial drainage, which is fracture controlled and therefore angular. The fault pattern causes trenches F and F1 marked by tree alignments. G1 is a massive granite with rounded forms but G2 is a strongly compressed variety, approching gneiss.
The forms are sharp, lamellated and resemble more schist than granite. This lamellation is caused by pegmatite dikes, which have greater resistance. (North park, Colorado)

Basalt effusion in arid climate



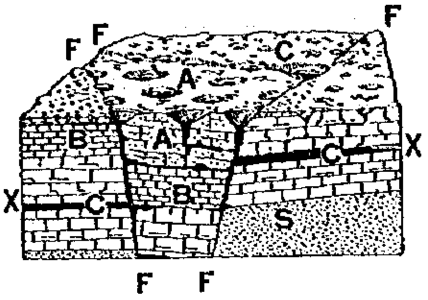
Injected into sediments (Sh), (S) the black fluid basalt lava reached the surface forming covers (B). The eruption took place along fissures, the system of cut-faults marked by dashed lines. Dikes (D) accentuate the fault system the eruption followed.
This is a split eruption type with sheet and dyke forms. The sediments are mainly shales in great part removed. Note typical silt-shale drainage pattern at bottom. Basalt with their contrasting dark tone are good tectonic indicators in arid regions. Note close spaced tree-like drainage pattern in silty shales (Sh) and no pattern in sand (S). (Central Arabia)

Strike-controlled sinkholes



Oval sinks (O) develop on tilted interbedded limestone beds (L). Sandstones (Ss) are permeable but insoluble,shales (Sh) are impervious. At X is a jagged scarp of arenaceous, lesssoluble limestone.

Fault-controlled sinkholes



Sinkholes show alignment and are deepest and broadest at cross-point of dislocations. Three types of limestones have large (A), medium (C), and small (B) sinks. At X is an Imprevious beds ; S, sand ; F-F, fault planes. Water drains into sand, follows enlarged fissures and bedding planes in limestone.

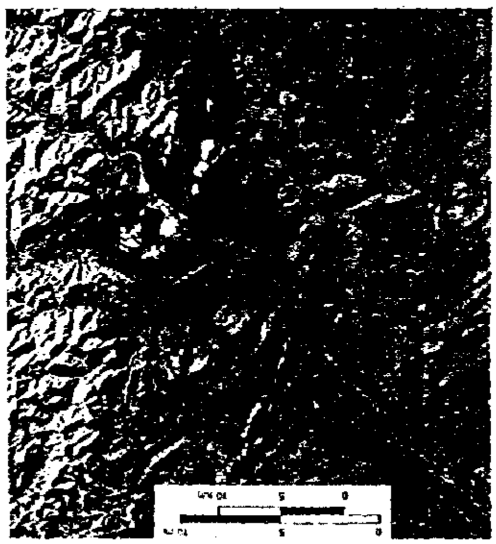
Lineament (Interpretation)

Lineament and foldings develops on the quartzite (ridge), and metapelite (valley) Near Alwar, Rajasthan

Lineament

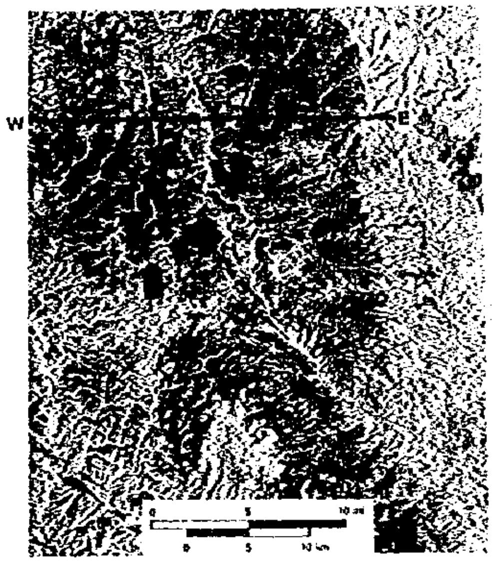
Lineament and foldings develops on the quartzite (ridge), and metapelite (valley) Near Alwar, Rajasthan

Thrust Fault



The transition from imbricate ridges to folds (at arrow) marks the frontal thrust of the Brooks Range at the Isshak River, Alaska. Thrusting here is from south or southeast to north or northeast. (by Landsat MSS image)

Fault

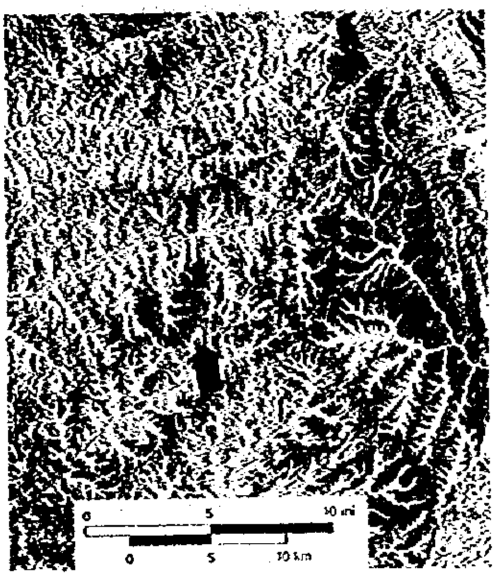


Landsat MSS color infrared images of the Rampart Range, Colorado, from Pikes Peak to Castle Rock. Arrows indicate faults parallel to the mountain front.

Fault Control

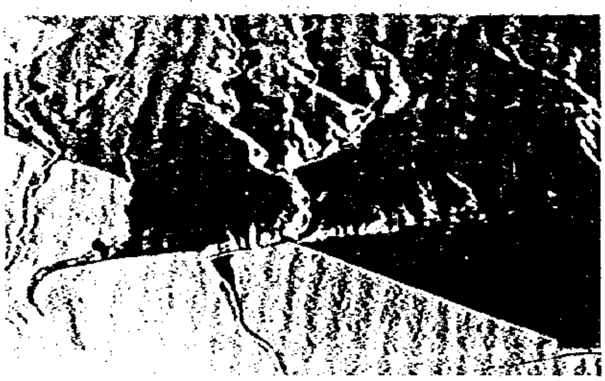
Vegetation (red) is alingned along springs, which in turn are controlled by faulting along the margins of spring valley, Nevada. Also note the paleo-shorelines at the north end of the valley.

Basalt Dyke Intrudes the Tertiary



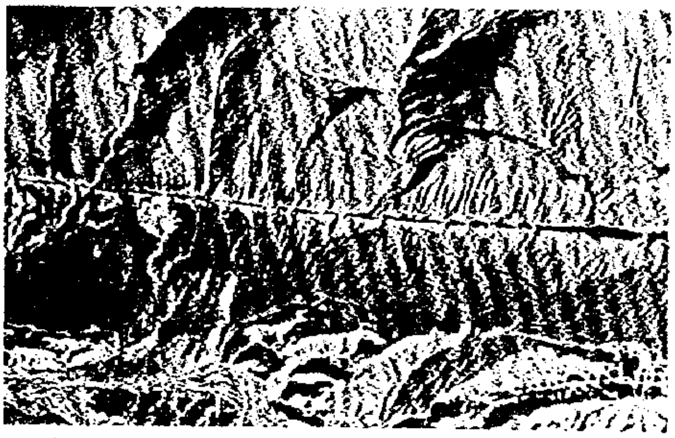
Basaltic dyke (arrow) intrudes the Tertiary in the northeastern San Juan basin, New Mexico. Intrusion was Contemporancous with jointing.

Tectonic Line



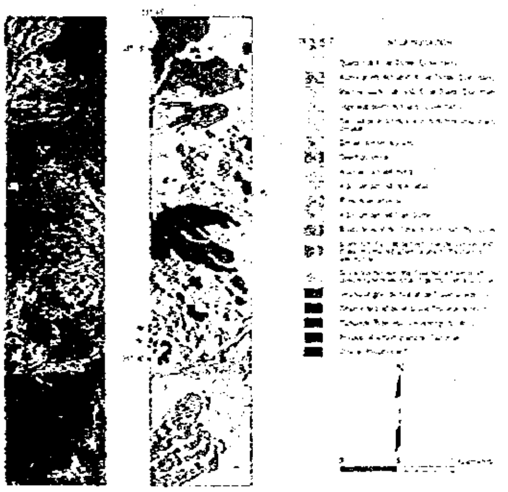
San Andreas Fault

Tectonic Line



Garlock Fault, Transverse Mts, California

Mapping



The surficial map was derived from the image. In general, quartz rich rocks are red ; alluvium is reddish pink (older) to red with a blue cast (younger) ; vegetation is yellow ; carbonates range from bright green to yellow ; quartzites are orange ; and basalts are dark blue-green.
(by Thermal Infrared Multispectral Scanner (TIMS), image of part of the Mojave Desert near Kelso, California).

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13 al 16 de octubre de 1998 • San Juan, República Argentina

Dr. Daniel Meilán
Subsecretario de Minería

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