The Geology of a Portion of the Santa Monica Mountains with a Section on Rock Cleavage

Benjamin Holzman

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Illustrations

Introduction

A section of the Santa Monica Mountains lying in the eastern third of the Reseda Quadrangle and a portion of the western third of the Van Nuys Quadrangle comprises the geological mapping investigated by this report. The occurrence of a very thick section of pre-Jurassic metamorphic sediments interested the writer to make a study of the rock fracture and cleavage as presented by this section, and the latter part of this report shall be devoted to the results of this study. R. Peterson and the writer chose adjacent areas so as to be able to present a clearer concept of the geologic history of the region. The investigation was carried on in connection with the Senior Problem Course at the California Institute of Technology.

The area can easily be reached by automobile by way of Ventura Boulevard or Mulholland Highway.

Physical Conditions.

Mulholland Highway follows the divide of the Santa Monica Mountains. The northern face of the mountains which forms the southern boundry of the San Fernando Valley is very much bolder and steeper than the southern face that flanks the ocean. The maximum elevations are approximately 1900 feet. From the divide the drainage flows northward into the San Fernando Valley, and Southward into the Pacific Ocean. The Encino Reservoir interrupts a portion of the former drainage into San Fernando Valley.

The area is very severely covered by brush and the dense foliation at times make it rather difficult for intensive mapping. The outcrops and exposures are plentiful and numerous road cuts facilitate the mapping. The cuts on Mulholland Highway are especially noteworthy. The fact that the shaly members of the Modelo will offer support only to a grassy growth is often an aid in mapping.

The region is infested with rattlesnakes.

Stratigraphy

Basement Complex

The basement complex is composed of a series of pre-Jurassic sediments that can now correctly be called slates. The age and thickness of this section are as yet indeterminate since the slates are unfossiliferous and correct attitudes of the bedding planes are difficult to ascertain. The age of the sediments can be determined to at least give the series an upper limit — for near by Cretaceous Chico unconformably overly the metamorphics. This would imply deposition during Jurassic or pre-Jurassic time. The slates were undoubtedly derived from previous siliceous, clayey, sandstone and shale members and vary in color from a brown to black. They are severely contorted and fractured and show excellent jointing. (See later discussion). The metamorphism is of a cataclastic and dynamo nature and probably incurred in the epizone. Talc, essentially a stress mineral, sometimes accompanies the slate. Occasional quartz veins, deposited by solution, can be found filling some of the fractures in the slates.

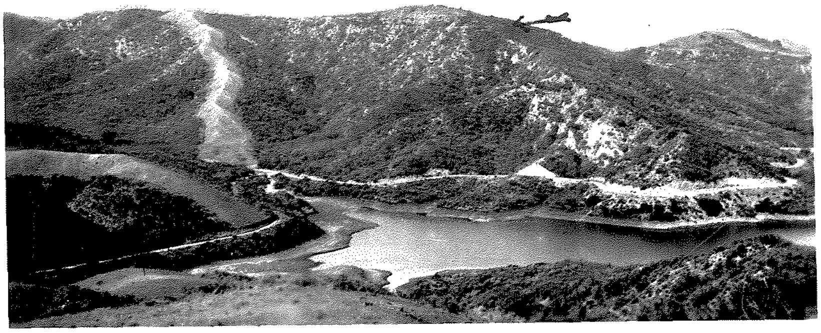
Granites of Jurassic age intrude the slates in part. This age is set by the fact that wherever the granites are exposed they only intrude the slates and not the overlying sediments. These exposures of granites are badly fractured and weathered — almost resembling a coarse grained sandstone.

Topanga Formation

Unconformably above the pre-Jurassic metamorphic sediments lies a series of brown, tan, sandstones and conglomerates. The beds are partly fossiliferous — restricted to sandstone members — and contain Turritella ocoyana. W. S. W. Kew in U.S.G.S. B. 753 has mapped this formation as the Vaqueros formation. However the Vaqueros formation is now being restricted to the Turritella inezana fauna. The Turritella ocoyana fauna is considered Middle Miocene. The beds are marine, extremely well indurated, and although very massive show distinct bedding planes. The base of the section is characterized by the hard massive sandstones and which grade up into a series of coarse conglomerates. A layer of extrusive andesites and basalts and which may in part be intrusive since the only evidence that might term the lavas extrusive is the vesicularity of some of the fragments, is present in the Topanga but its relationship is somewhat obscured. The conglomerate of the Topanga contain well rounded to subangular boulders and pebbles with frequent fragments of andesite and basalt. The field relationship at the contact of the Topanga and overlying Modelo was very obscure due to the sparsity of exposures and a covering of alluvium. The Modelo however is characterized by its shale members and this is perhaps the chief lithologic differences between the Modelo and Topanga. The Topanga has no shale members. The maximum thickness of the Topanga formation as demonstrated by this area is approximately 3000 feet.

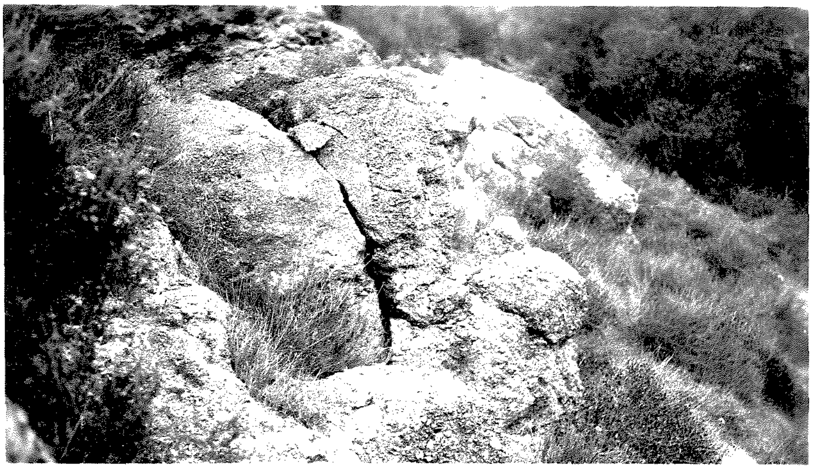
Modelo Formation

Overlying the Topanga and the pre-



Modelo lying unconformably upon slates
(arrow pointing to contact)

Close up view of above picture



Basal conglomerate of Modelo.

Jurassic metamorphics in part occurs the Modelo Formation. The unconformity between the Modelo and Topanga is indicated by an interformational conglomerate. The basal Modelo consists of a conglomerate that contains well rounded pebbles and fragments of the underlying slates. The conglomerate is rather singular in that its matrix is a well sorted sandstone. The conglomerate immediately grades into a hard brown massive sandstone. This basal Modelo grades into a clay, diatomaceous shale, and fine-grained sandstone containing lenses of coarse brown and tan sandstone. Macro-fossils seem to be entirely absent from the formation but its stratigraphic position places its age as Upper Miocene. W. S. W. Kew in U.S. G. S. B. 753 makes a separation of the Modelo into certain members and distinguishes the Modelo from a supposed Pico formation. Since this series is without fossils - at least macro fossils, and the field relationships seemed to indicate no essential difference as to unconformities and etc. I had no alternative but to accept that the series was continuous and of one formation that of the Modelo. The Modelo in this area seems to have an approximate thickness of 2300 feet, but is undoubtedly much thicker.

Quaternary Alluvium

This of course is the recent unconsolidated sands and gravels brought to the San Fernando Valley by the drainage. It is interesting to note that the lowest part of the Valley is that portion that flanks the Santa Monica Mts. This means that the southern end of the San Fernando Valley is rapidly being aggraded, and one should normally find the thickest deposit of alluvium at the southern flank.

Structure

The geologic structure of the area is relatively simple. Unconformably upon the pre-Jurassic metamorphic sediments lies the Topanga formation. The general attitude of these strata is approximately N 75E 55 N. Unconformably upon the Topanga lies the Modelo which has the same general strike but whose strata dip from 50° to 20° to the north. The section then has a monoclinal aspect that may be interpreted as being the northern limb of a broad syncline.

One major fault - that designated as C-D on the map - occurs in the region. On the north side of the fault Topanga and slates have been faulted up relative to a down faulting of the Modelo on the south side of the fault. It is interesting to note that the Modelo on the south side of the fault lies directly upon the slate indicating an overlap of the Modelo on the Topanga formation. The attitude of the plane of the fault as ascertained from exposures along Mulholland Highway seems to be almost vertical.

Fault.

Metumorphic sediments at left. Modelo at right.

Fault.

Metamorphic sediments at left. Modelo at right

One of the striking features of the fault is the lack of the usual characteristic features that accompany a fault. Breccia; gouge, drag folding are not ~~at~~ at all conspicuous features. There has been however a slight amount of fracturing on either side of the fault plane. A rough calculation from the structure section shows the apparent displacement to be approximately 2500 feet.

Fault E-F is an entirely obscure one. A fault was the only solution to explain the stratigraphic relationships as shown upon the map. If a fault were not drawn an anomalous condition would then present itself. Structurally older beds, Topanga would overly younger beds, Modelo; fault E-F remedies this condition.

Historical Geology

In pre-Jurassic time deposition of the present metamorphic sediments began. During Jurassic time granites were intruded in the undisturbed sediments. My basis for this belief are the facts that the granites are wholly confined to the slates and that where the granites are found exposed, they are badly fractured. This latter fact seems to indicate that the intrusions of granite took place before the metamorphism of the sediments — otherwise one might normally expect the granite to be in an unfractured condition.

An extremely long period of erosion took place and in Middle Miocene time the Topanga formation was deposited. During the deposition of the Topanga, igneous activity became apparent and consequently andesite and basaltic flows and fragments became incorporated in the Topanga formation. The deposition of the Topanga ceased when a period of uplift occurred. The Topanga had undergone only a slight period of erosion when the seas again encroached upon the land.

The deposition of the Modelo began with a basal conglomerate. The seas were quite extensive because the Modelo considerably overlaps the Topanga.

In Pliocene time the seas withdrew and from then to the present diastrophism played an important part. A regional uplift took place with accompaning faulting. Displacement along Fault C-D caused a relative movement of approximately 2500 feet. The beds became tipped as a result of the uplift to their present homoclinal attitude.

Rock Fracture as Illustrated by the Pre-Jurassic Metamorphic Sediments.

C. K. Leith on page 24 in "Structural Geology" declares the following, "Given a rock structure in which the directions of elongation and shortening, or in other words, the position of the strain ellipsoid, is known, it is possible to locate to locate the planes of maximum shear, without regard to whether the stresses have been tensional or compressional, rotational or non-rotational."

I do not believe this statement is entirely correct and in the following I shall give my proofs.

The theoretical shear of an object under stress occurs at 45° to the principal axis of the stress — but this will only occur if the object is of a homogeneous nature and the ratio of the ultimate tensile to ultimate compressive strengths is equal to one.

Leith's strain ellipsoid assumes that the elongation in the direction of one principal stress equals the shortening in the direction of the other principal stress, or that the area of the strained surface remains unchanged. A mathematical consideration shows that when a circle is changed into an ellipse of equal area, the angle of the lines of no distortion facing the direction of shortening must alway exceed 90°, or in other words the shearing must alway exceed 45° to the axis of stress.

$\pi r^2 =$ area of circle

$\pi ab =$ " " ellipse

Given $\pi r^2 = \pi ab$; $r^2 = ab$

$x^2 + y^2 = r^2$ (circle)

$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ (ellipse $a > b$)

$$y^2 = r^2 - x^2$$

$$\frac{x^2}{a^2} + \frac{r^2 - x^2}{b^2} = 1$$

$$x^2 b^2 + a^2 r^2 - a^2 x^2 = a^2 b^2$$

$$x^2(b^2 - a^2) = a^2 b^2 - a^2 r^2$$

$$x^2 = \frac{a^2(b^2 - r^2)}{b^2 - a^2}$$

but $r^2 = ab$

$$x^2 = \frac{a^2 b(b-a)}{(b+a)(b-a)}$$

$$x^2 = \frac{a^2 b}{a+b} \quad ; \quad x = \pm \frac{a\sqrt{b}}{\sqrt{a+b}}$$

$$x^2 = r^2 - y^2$$

$$\frac{r^2 - y^2}{a^2} + \frac{y^2}{b^2} = 1$$

$$b^2 r^2 - b^2 y^2 + a^2 y^2 = a^2 b^2$$

$$y^2(a^2 - b^2) = a^2 b^2 - b^2 r^2$$

but $r^2 = ab$

$$y^2 = \frac{ab^2(a-b)}{(a+b)(a-b)}$$

$$y^2 = \frac{ab^2}{a+b} \quad ; \quad y = \pm \frac{b\sqrt{a}}{\sqrt{a+b}}$$

$\therefore \tan\theta = \frac{x}{y} = \frac{\sqrt{a}}{\sqrt{b}}$ and which can not be at 45°.

4-

I have stated above that the theoretical angle of shear at 45° will only hold if the body is homogeneous and if the ultimate tensile and compressive strengths are equal. This latter fact is fundamental and most important but is usually forgotten. Leith's strain ellipsoid does not introduce this important factor. Strongly ductile materials such as soaps shear at very obtuse angles, whereas the angle of shearing is more acute the more brittle a substance is.

In investigating the shearing in the Pre-Jurassic slates I found that in all cases the angle of cleavage departed considerably from the theoretical value of 90°. The following tests were made at intervals along the cut exposed on Mulholland Highway.

#	obtuse ∠	acute ∠	#	obtuse ∠	acute ∠
			6.	106	74
1.	110	70	7.	98	82
2.	110	70	8.	100	80
3.	120	60	9.	105	75
4.	110	70	10.	106	74
5.	104	76	11.	104	76

From Mohr's Theory of Rupture the following formula is derived —

$$\cos \theta = \frac{\sigma_c - \sigma_t}{\sigma_c + \sigma_t}$$

where σ_c = ultimate compressive strength
σ_t = " tensile "

This formula connects the angle of shearing with two important physical constants — the ultimate tensile and compressive strength. The derivation of this formula is rather tedious and is presented in recent textbooks on Strength of Materials and also by Louis Brand in the Journal of Geology Vol 29 #1 pp. 1.

Knowing the angle of shear a ratio of the ultimate compressive to tensile strength can be obtained.

$$\cos \theta = \frac{\sigma_c - \sigma_t}{\sigma_c + \sigma_t}$$

Let $K = \frac{\sigma_c}{\sigma_t}$

$$\therefore \cos \theta = \frac{K - 1}{K + 1}$$

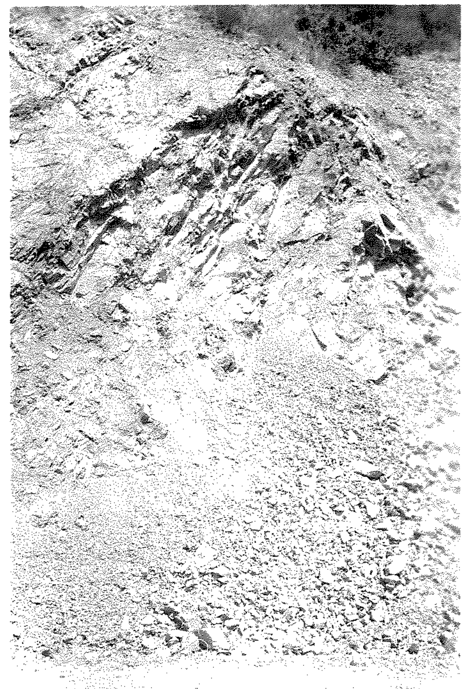
According as the ultimate compressive strength is greater than, equal to, or less than the ultimate ~~shear~~) tensile

(~~tensile~~) strength the angle of shearing will be an acute, right or obtuse angle.

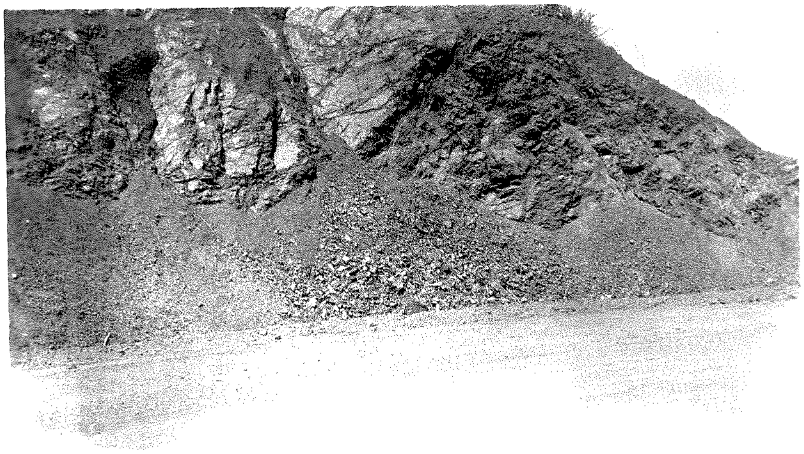
In plotting a number of the attitudes of some major shearing planes, it was found that no dominant trend prevailed and that the stresses applied to cause the shearing must have been of an extremely heterogeneous nature.

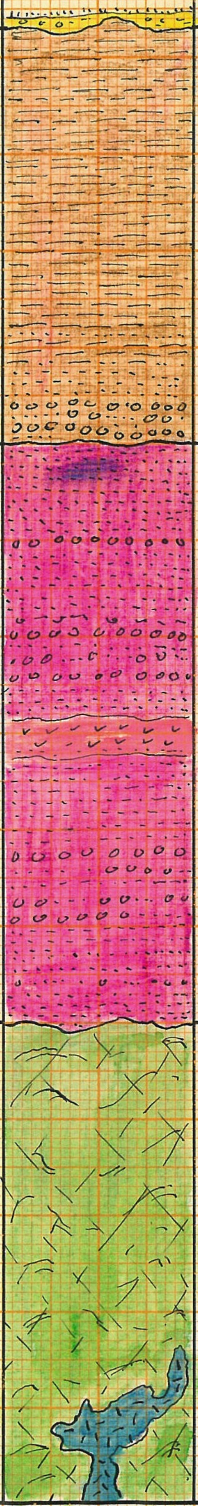
Conclusion: Although Leith's strain ellipsoid presents a rather simple and easy method to visualize the nature of shear, it is not at all accurate and correct, and I should like to suggest Mohr's Rupture Formula to the application of shearing phenomena in rock fracture.

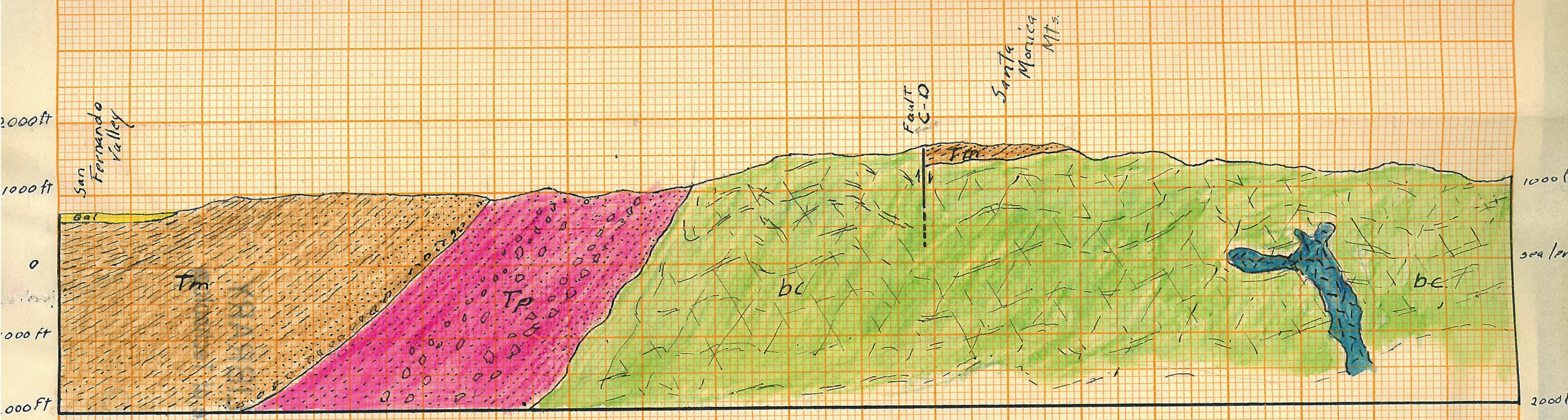
Rock Fractures in Pre-Jurassic Metamorphics.



Rock Fracture in Pre-Jurassic Metamorphics



System	Formation	Symbol	Columnar Section	Thickness	Character
Recent	Alluvium unconformity	Qal		50'±	Recent gravels and sands now being deposited
Upper Miocene	Modelo unconformity	Tm		2300'±	Largely siliceous, clay, and diatomaceous shales. Lenses of sandstone frequently interbedded. At base occurs conglomerates and sandstones
Middle Miocene	Topanga [Andesite + Basalt] → Tab unconformity	Tp		3000'	Pimarily brown sandstones, partly fossdiferous. Andesite and basalt are interbedded in sandstones. Conglomerates also interbedded.
Pre-Jurassic	Metamorphic Sediments Intrusive granite	bc (gr)		unknown	Slates. Metamorphic sediments of Pre-Jurkassic age. Intrusive granites also present.



San Fernando Valley
Santa Monica Mts.
Fault C-D
2000 ft
1000 ft
0
sea level
Qal
Tm
Tp
bc

Section A-B