The Geology of a Portion of the Redlands Quadrangle, California; a Study in Faulting.

by L. W. Bolles.

TABLE OF CONTENTS

Small scale map showing location of area.

Bibliography....................................page 1.

Introduction....................................." 2.

Summary.. " 3a.

Physical conditions.............................. " 4.

Stratigraphy and petrography

The stream gravels........................ " 5.

The Quaternary alluvium................. " 7.

The Potato Sandstone..................... " 8.

The granodiorite.......................... " 10.

The basement complex.................. " 12.

The Crafton Hills schists.............. " 13.

Geologic structure

Faulting

General conditions.................14.

Faults A, B, J, K, and L............15.

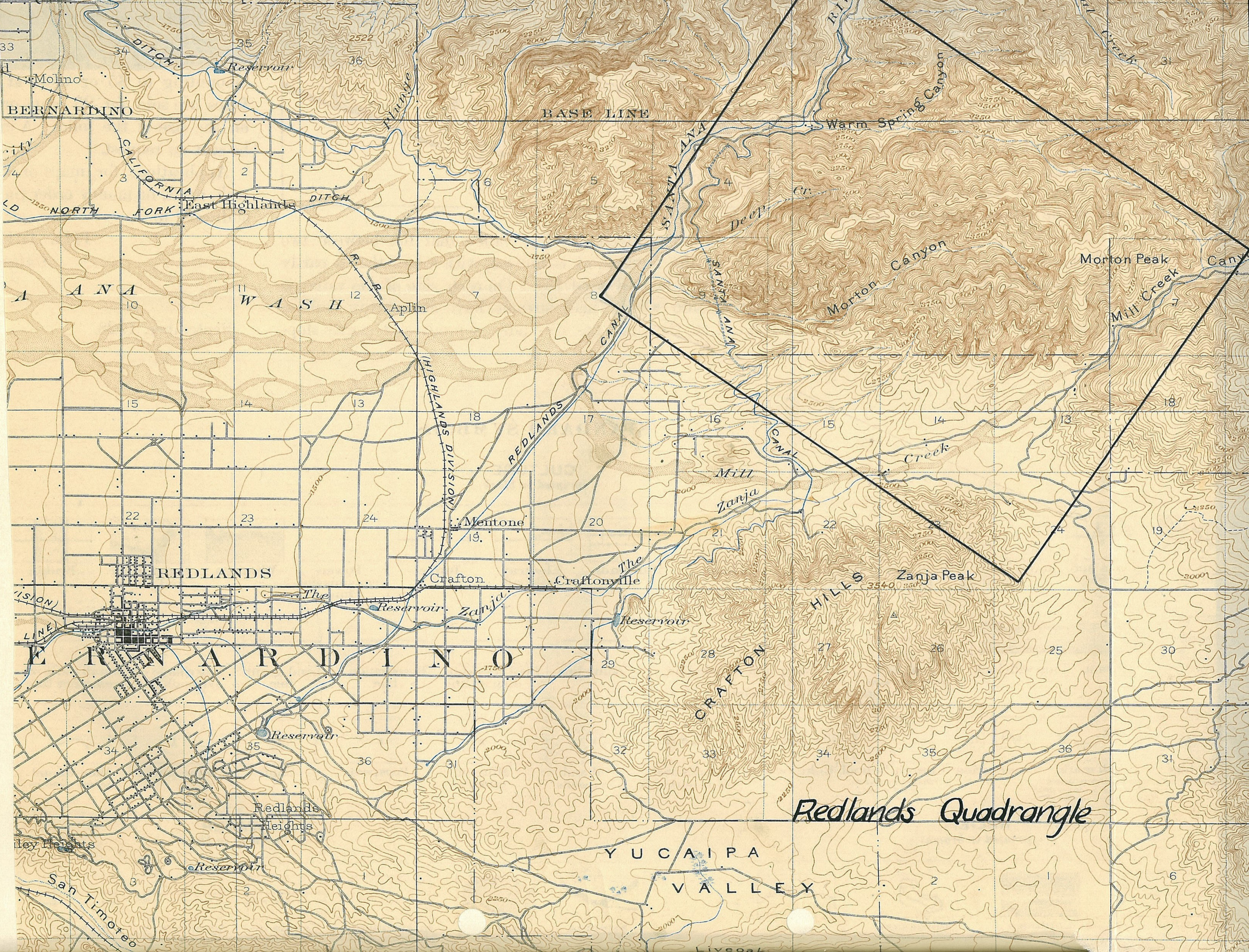
Fault C.............................16.

Faults M, H, and E.................17.

Faults G and D.....................18.

Fault F.............................19.

Fault I.............................20.



Molino
BERNARDINO
Reservoir
DITCH
BASE LINE
Warm Spring Canyon
CALIFORNIA
NORTH FORK
East Highlands
DITCH
SANTA ANA
Deep Cr.
Morton Canyon
Morton Peak
Mill Creek
WASH
Aplin
R. R.
HIGHLANDS DIVISION
CANAL
REDLANDS
Mill
Creek
Zanja
Mentone
REDLANDS
Crafton
Craftonville
The
Zanja
Reservoir
Zanja Peak
CRAFTON
HILLS
ERNARDINO
Reservoir
Redlands
Heights
Reservoir
San Timoteo
YUCAIPA
VALLEY
Redlands Quadrangle

BIBLIOGRAPHY

Francis Edward Vaughan did the early work on the region to the east of this area but did not work far enough west to cover any of the area mapped by the author.

The most detailed work previously done on a portion of the area was the work on the San Andreas Rift by Dr. George Cumming. In general the author quite agreed with his conclusions and confined the larger part of his work to the area to the north of the San Andreas Rift.

Woodford is included to indicate that his work on the San Onofre Breccia is the type that should be done in the Potato Sandstone.

The author believes that the area mapped along the Mission Creek Fault has never before been studied in any detailed manner.

(1) George Cumming, Geology of a Portion of the San Andreas Rift. Unpublished. California Institute of Tech.

(2) F. E. Vaughan, Geology of the San Bernardine M'tns North of San Gorgonio Pass, Univ. Calif. Publ., Bull. Dept. Geol., Vol.13, No.9.

(3) A. O. Woodford, The San Onofre Breccia, Its Nature and Origin, Univ. Calif. Publ., Bull. Dept. Geol. Vol.15, No. 7.

(4) L. F. Noble, Report of the Advisory Committee in Seismology, Carnegie Inst. Year Book, No.25, 1925-26. Pp. 419-420.

INTRODUCTION

The San Andreas Rift after passing through the Cajon Pass in Southern California proceeds approximately S 60° E along the base of the San Bernardino Mountains which rise to the north. About eight miles east of the city of Redlands Mill Creek issues from the San Bernardino Mountains south-west on to the alluvium covered flood plain. Four miles to the west the Santa Ana River cuts north and south through the crystalline rock. These two streams roughly mark the east and west boundaries of the area studied. The southern boundary is in reality the San Andreas Rift although the edge of the Crafton Hills is shown. The northern boundary is the Mission Creek Fault which is followed by Mill Creek as far west as the north-east corner of the geologic map shown in this report.

The area studied covers approximately fifteen square miles in area. The maximum variation in elevation is about 2500 feet.

The area was chosen to be studied for several reasons. The foremost reason was because the region was most ideal for the study of faulting. The area contains thirteen mapped faults, large, small, normal, overthrusts, old, and recent. Six formations could be studied and research could be done on a comparitively unexplored area. The author also made a very prolonged search for fossil material in the Potato Sandstone, a formation whose age is only known roughly from paleobotanical evidence. This portion of the research was doomed to failure but the study of the region opened up so many problems of great geological interest that the author has never had occassion to regret in the least the time spent.

SUMMARY

The area mapped contains 13 mapped faults. Faults A, B, J, K, and L are a part of the San Andreas Rift Zone; all probably show recent strike-slip movement, the southern part having moved north-west and the northern part having moved south-east. The total magnitude of the movement is not known but if origin of the Potato Sandstone from the schist series (of which Crafton Hills is a part) can be shown the total movement from time of deposition of the sandstone may be determinable.

The Mission Creek Fault (fault C) is a steep overthrust fault dipping north. It is marked by a broad band of brecciation. The total movement is not known but the fault is still active. Faults M, H, and E may be a part of the Mission Creek Fault system but little is known of them. Fault D-G is an old vertical fault contacting the Potato Sandstone and the Granodiorite. Fault F dips slightly south and has faulted fault D-G approximately 3950 feet in horizontal component. Fault I is tentative and probably marks the remaining bench of an old land surface.

The Potato Sandstone is a coarse, hard, arkosic sandstone with some conglomerate containing angular schist and granite boulders. It has a minimum thickness of 2000 feet, is complexly folded and badly shattered near its southern border. From paleobotanical evidence it is tentatively considered to be Pliocene in age. No

other fossil material was found.

The crystalline rock west of the Potato Sandstone consists of badly decomposed granodiorite cut by numerous dikes of aplite.

The schists are a micaceous and sericitic variety cut by granite dikes. The dip is approximately 20° south.

The alluvium covers most of the area mapped south of the Rift and is at minimum 200 feet thick.

Stream gravels vary in composition according to their source. Those from the east part of the area are mostly Potato Sandstone; those in the western portion are largely crystalline.

The basement complex consists of undifferentiated igneous and metamorphic rocks, probably gneisses and schists to a large extent.

The San Andreas Rift is the most important feature in the area but less work was done by the author on it than on the geology to the north because the geology of the Rift region has been so ably covered by Dr. George Cumming.

PHYSICAL CONDITIONS

The region is quite precipitous everywhere to the north of the San Andreas Rift. A few miles to the east of the area San Gorgonio Peak rises to over 11,000 feet in elevation. This mountainous region is cut by steep-walled canyons such as Santa Ana Canyon and Mill Creek Canyon. The portion of Mill Creek Canyon which follows along the zone of the Mission Creek Fault is marked on the north by several hanging valleys with waterfalls emptying into Mill Creek Canyon. The greatest topographic feature in the area, however, is the line formed by the San Andreas Rift. To the north of the rift rise the San Bernardino Mountains, precipitous and rough. South of the rift stretches the alluvial fan, fertile ground for rich citrus groves. The rift is the line of demarcation for every structural feature except the stream gravels and some of the more recently deposited alluvium.

Most of the slopes north of the rift are heavily covered by brush although a large part of the Potato Sandstone has been burned over recently.

STRATIGRAPHY AND PETROGRAPHY

The Stream Gravels.

The stream gravels are probably the most recently laid down deposits in the region and are presumably Recent or Late Pleistocene in age. They vary in composition depending upon the source of the boulders and gravel. In the stream bottom bordering the schists in the extreme southeast corner of the map the boulders were observed to consist of 8/10 sandstone, 1/10 conglomerate, and only 1/10 crystalline rocks. It is apparent that the source of the materials is almost entirely the Potato Sandstone in this stream bed. In Warm Spring Canyon just before it enters the Santa Ana River the boulders were observed to consist of 4/5 crystalline rocks and 1/5 sandstone. The 1/5 was apparently all that the Potato Sandstone contributed although nearly half of the fault canyon consists of sandstone. There are more streams, however, entering the fault canyon from the north than from the south.

Section in Mill Creek just above point where stream enters Santa Ana River; showing unconformity between alluvium and stream gravels.

The Quaternary Alluvium

Practically all of the area south of the San Andreas Rift with the exception of the Crafton Hills is covered with a thick layer of quaternary alluvium. The thickness is apparent in the Morton Canyon ridge as exposed in cliffs along the Santa Ana River. It is at least 200 feet thick in places and probably is very much thicker than that. There are very surely several different periods of deposition represented but no attempt was made to differentiate them. Although the alluvium, as shown on the geologic map, is confined entirely to the south of the San Andreas Rift to the west of Mill Creek Canyon the rift does not mark the border to the east of Mill Creek. This farthest north alluvium is probably younger than the main mass of alluvium.

Alluvial terraces of greater or lesser extent are shown in Santa Ana River Canyon. Except for the terrace at the mouth of Warm Spring Canyon the areas covered are inconsequential. The alluvium covered hollow in the Crafton Hills is fertile being planted mainly to grapes.

Typical exposures of Potato Sandstone.

At mouth of Mill Creek Canyon; cliff approximately 1200 feet high.

North of Morton Peak.

The Potato Sandstone

The portion of the Potato Sandstone studied consists of arkose varying from a few layers of intercalated shales through the main mass of coarse material to a hard conglomerate of angular schist, and some granodiorite, boulders to the east. In the area studied the Potato Sandstone is bounded on the north by the Mission Creek fault, on the south by fault F and the San Andreas Rift; it is separated from the granodiorite to the west by fault D , and the eastern border (not shown) is another faulted contact.

The Potato Sandstone lies between two major faults and for that reason is badly shattered, particularly near the faults C and A. The folding is rather complicated and minor faults (unmapped) have added to the complication. The folds in general are simple (not composite) but they are certainly complex (with folded axes). The beds are quite competent; the shale members are very thin and no exception. The change in attitude of the beds as they approach fault D indicates (rather uncertainly) that the west side of fault D <u>may</u> have moved up and to the south with reference to the Potato Sandstone to the east. Along the Mission Creek fault the strike of the beds closely parallels the fault and the consistent southward dip may indicate vertical movement of the crystallines to the north of the fault.

The origin of the Potato Sandstone is as yet unknown although Noble [(1)] indicates the probability

(1) L. F. Noble, Report of the Advisory Committee in Seismology, Carnegie Institution Year Book, No. 25, 1925-26. Pp.419-420.

that it was derived from the Schist series of which the Crafton Hills is a part. As the Potato Sandstone and the Crafton Hills schist series are on opposite sides of the San Andreas Rift such an origin of the sandstone might very probably indicate the horizontal component of movement on the Rift since deposition of the sediments. A petrographic study of the Potato Sandstone is highly adwisable.

Vaughan, doing the earliest work in the region, tentatively places[2] the age of the Potato Sandstone as Miocene upon a basis of lithologic similarity with the Miocene Puente Sandstone of the Santa Monica Mountains. Later estimates based on paleobotanical discoveries have indicated that the Potato Sandstone is probably Pliocene in age[3]. The exact age, however, will probably not be determined until invertebrate or (more probably) vertebrate remains are found. The Potato Sandstone is probably of continental origin.

(3) George Cumming, Geology of a Portion of the San Andreas Rift. Unpublished. California Institute Of Tech.

(2) F.E.Vaughan, Geology of the San Bernardine Mountains North of San Gorgonio Pass, Univ. Calif. Publ., Bull. Dept. Geol., Vol. 13, No. 9. P.375.

The Granodiorite

The area between the San Andreas Rift and Mission Creek Fault west of fault D consists of a badly decomposed slice of granodiorite cut by numerous aplite dikes. Large areas of the granodiorite are badly shattered particularly near the San Andreas Rift. Two faults only cut the granodiorite; faults F and J. Fault F has acted later than fault D , fault C ~~earlier~~ later than fault F.

The Basement Complex

The Basement Complex consist of gneisses and schists, entirely undifferentiated. No work was done in the region north of the Mission Creek Fault except on the structural relationships due to faulting. Apparently the rocks north of the Mission Creek Fault have been overthrust upon the Potato Sandstone and the Granodiorite.

The Crafton Hills Schists.

The region in the extreme south-east corner of the map borders the northern side of the Crafton Hills which consist of a somewhat decomposed schist. The schist is in part micaceous, in part sericitic and is intruded by many dikes, sills and veins of various size and composed almost universally of granite. The schist has a very consistent dip of about 20° to the south. The attitude at one locality is shown on the extreme eastern border of the map.

GEOLOGIC STRUCTURE

Faulting

General Conditions.

The major fault feature of the region is the San Andreas Rift. The Mission Creek Fault contacts at both of its ends with the San Andreas Rift, the region between the two faults being something in the nature of a slice. Thus, the area included in this report lies largely within this slice, some overlapping being shown to the north and south to obtain a clear conception of the zones of faulting. The San Andreas Rift is, in reality, not a single fault but a zone of faulting. To this zone belong faults A, B, J, K and L. The Mission Creek Fault is mapped as a single fault (fault C). There are, however, several faults to the north of fault C, namely faults E, H, and M whose parallel arrangement suggests a common origin with fault C. There are only two faults of importance that do not belong either to the Mission Creek or the San Andreas Fault systems; these are faults D and F (assuming that G and D are the same fault). They divide the Potato Sandstone to the east from the Granodiorite to the west.

The faults may be roughly grouped as to size:

Large: Faults A, B, J, K, L and C. That is, the San Andreas Rift Zone and the Mission Creek Fault.

Medium: D, E, F and G.

Small: Faults H, I, and M.

Looking east up Morton Canyon from Santa Ana Canyon; i.e. looking east along the San Andreas Rift. Morton Canyon, in the view shown, is an erosional valley following exactly along the Rift, a course nearly at right angles to its original direction in the upper half of its extent.

Faults A, B, J, K and L.

The San Andreas Rift is a zone several hundred feet wide consisting of a system of interlacing and interconnected faults. The fault zone may be traced across the country with no difficulty by ridges, depressions, kerncols and kernbutts, fault scarps and back slopes, fault erosion canyons, springs and sycamores, offset canyons, truncated spurs, disarranged drainage, but oddly enough not the wide and colorful zone of brecciation marking the Mission Creek Fault.

Movement along the Rift has been shown to be largely, if not entirely, horizontal, the faults being mainly of a strike-slip nature. The southern side of the fault apparently has always moved to the north-west, the northern side to the south-east.

The question of which fault or faults in the Rift system has suffered the greatest movement is not determinable with present known data but it is not a question of any great importance. The relation of the individual faults to each other is, at the present stage of our knowledge, completely overshadowed by the greater importance of determining the total amount of movement along the San Andreas Rift. As Cumming has pointed out[7] a petrographic study of the Potato Sandstone with reference to its possible origin from the schist series across the Rift might well give the amount of movement on the San Andreas Rift since the Potato Sandstone was deposited.

The Mission Creek Fault (fault C) looking west from Santa Ana Canyon; The fault is dotted. The solid horizontal line marks the top of the rock cut bench and the bottom of the quaternary terrace alluvium lying conformably upon the bench.

Fault C.

Fault C is the main fault of the Mission Creek Fault so named from Mission Creek near San Gorgonio Pass. Vaughan and Cumming agree that it is a reverse fault dipping steeply to the north. Near City Creek (several miles west of the area studied by the author) the Mission Creek Fault is said to dip nearly vertically, the dip becoming less to the east.

Fault C is clearly marked by a band varying from 25 to 200 feet in width consisting of a bright red zone of breccia and gouge. West of the Santa Ana River the fault may be easily traced bya straight, deep depression, apparently an erosion feature.

The fresh appearance of the breccia in places and facility with which the erosional valleys may be traced gives the impression that the Mission Creek Fault has suffered movement as recently as the San Andreas Rift; both of them are active faults.

Faults M, H and E.

Faults M, H, and E are probably closely related to fault C, the Mission Creek Fault. Movement on faults M and H does not appear to have been large but fault E is marked by a deep and straight depression which is very marked; the indication is that movement on fault E was either large or recent.

The faults M, E, and H all lie entirely in the basement complex and are evidenced only by topographic features such as deranged drainage, ridges and valleys, kerncols and kernbutts, not by change in lithology as the fault is crossed.

Probably the faults are overthrusts of the nature of fault C. Fault E, at least, has not shown ~~moved~~ activity since last movement on the Mission Creek Fault as evidenced by the cutting of fault E by fault C.

FAULT D

Taken at the intersection of the ridge northwest of Morton Peak with Fault D. Looking S15°E along the fault. Note that the sediments to the left are higher than the crystallines to the right.

The dotted line shows fault D looking north from Mill Creek Canyon. To the right of the fault is Potato Sandstone(black, interbedded with black conglomerate); to the left is granodiorite

Faults G and D.

The faults G and D as well as a portion of fault F serve to be the line of contact between the Potato Sandstone and the Granodiorite. Fault D and fault G are thought to have been continuous until displaced by fault F.

Fault D is exposed in cross section on the west side of Mill Creek Canyon. It appears here to be a vertical fault. The Potato Sandstones are practically horizontal where they meet the fault plane. There is no brecciated zone of any size at the Mill Creek Canyon exposure but a short distance to the north a brecciated region is prominent and continues so to the extreme northern end of the fault.

It was not possible to determine the direction or magnitude of movement. The fault is older than fault F which in turn is older than fault C.

Near the southern end of fault D will be seen outlined a landslide. Here a large mass of Potato Sandstone has landslided in a southwest direction leaving a considerable marshy area of depression on the upper side. Cumming mapped this area as being faulted southwest by three curved faults. The author found no evidence of these faults but did find very good evidence of landsliding on a large scale. A region located so close to an active fault of as great magnitude as the San Andreas Rift might well be expected to show such effects of strong earth tremors. The author has seen the same thing along the Rift in the vicinity of Sandberg.

Dashed line shows ridge offset approximately 50 feet by fault F.

Fault F.

The final movement on fault F is intermediate in time between movement on fault D and on fault C. Fault F displaces fault D approximately 3,950 feet horizontally and this distance may be taken to represent the horizontal component of movement along fault F.

Along its eastern end fault F may be traced by a 5 to 20 feet wide zone of brecciation, the contact between the Potato Sandstone and the Granodiorite, and by saddles. Farther west the saddles and zone of brecciation continue but are ultimately lost in Deep Creek. Fault F appears to have a slight dip to the south.

Fault I.

Along what is shown as fault I on the map there is a break in the steep slope and there is a bench in the Potato Sandstone covered by alluvium. Cumming calls this the remnant of an old land surface. The author has tentatively mapped fault I along this line although the evidence for the fault is somewhat scant. Besides a few topographic features indicating the possibility of a fault a decided change in dip of beds is to be noted passing from one side of the fault to the other.

Aeroplane photograph of mouth of Mill Creek Canyon and vicinity. A large part of the Rift was mapped on such photos.