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HOST-ROCK INFLATION BY VEINS AND DIKES AT GRASS VALLEY, CALIFORNIA.

ROLLIN FARMIN.

Reprinted from Economic Geology, Vol. XXXVI, No. 2,
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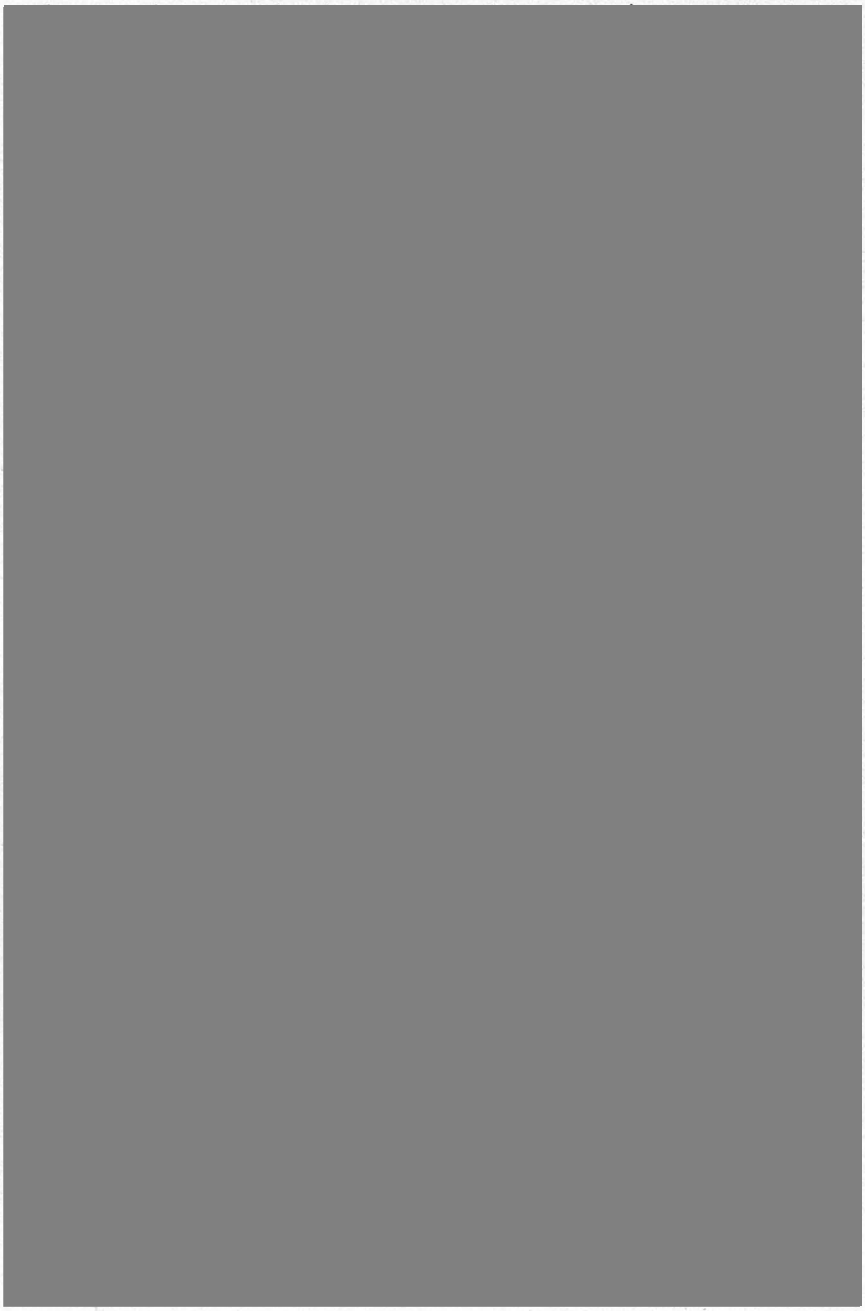
ABSTRACT.



STRUCTURAL HISTORY OF THE FRACTURE SYSTEMS AT GRASS VALLEY, CALIFORNIA.

W. D. JOHNSTON, Jr., and ERNST CLOOS.

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Reprinted from Economic Geology, Vol. XXIX, No. 1,
January–February, 1934.

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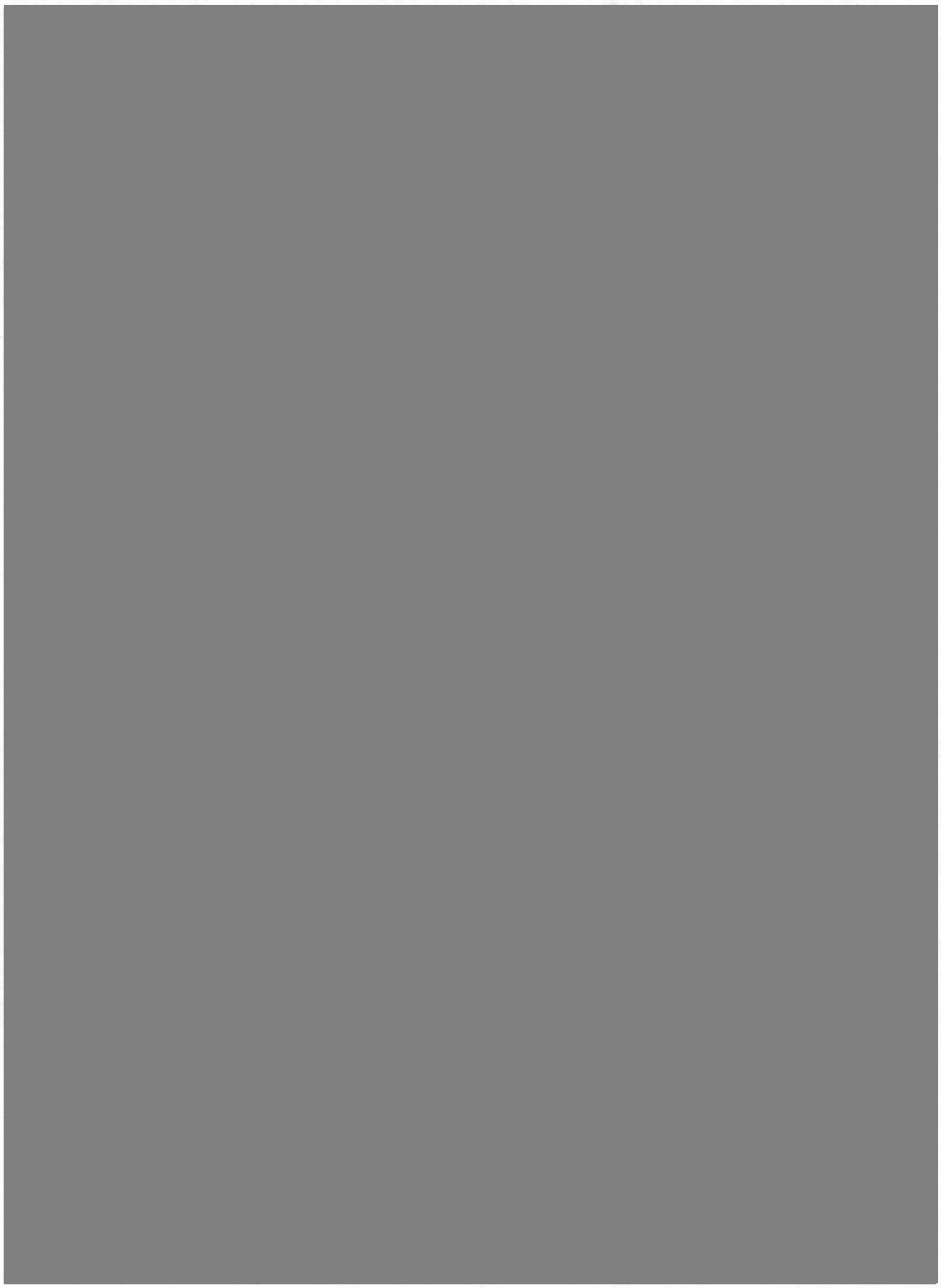
INTRODUCTION.



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This article appeared in the September–October number (No. 6, vol. XIX.) of ECONOMIC GEOLOGY; additional copies of the number can be obtained from W. S. Bayley, Business Editor, Univ. of Illinois, Urbana, Ill., at 65 cents per copy. Secretary, Society of Economic Geologists, Room 1413, 42 Broadway, New York City.

D. H. McLaughlin

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SOCIETY OF ECONOMIC GEOLOGISTS
PUBLICATION NO. 37

November, 1924

D. H. McLAUGHLIN
ROTCH BUILDING
CAMBRIDGE, MASS., U. S. A.

THE GOLD ORES OF GRASS VALLEY, CALIFORNIA

ERNEST HOWE

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Ore Deps. Ass't. with Flat Faults Wisser Jn. Aug. '38 Ideas

THE ENVIRONMENT OF REGIONAL SHEAR OR COMPRESSIONAL FRACTURE PATTERNS.

Certain districts show, or appear to show, definite shear or compression fracture patterns; others do not. It is pertinent to analyse the descriptions available of these two types of regions, in order to find out, if possible, the underlying causes for the presence of such fracture patterns. The problem may be simplified as follows.

The underlying cause for a district shear or compression pattern is obviously regional shearing or compressional stress. Possible modifying factors, that may modify or wholly prevent such patterns , are, non-homogeneous walls rocks and preexisting, unfavorably oriented fracturing. Hence complete analysis calls for an explanation of the regional stress in a district, together with a description of the country rocks, and an explanation of how the rock and the preexisting fracture pattern have modified the theoretical shear or compression pattern. The simplest case would be completely homogeneous rock and uni-stage compression. An effort will be made to describe first what appear to be the simplest cases, leading from them to more complicated examples.

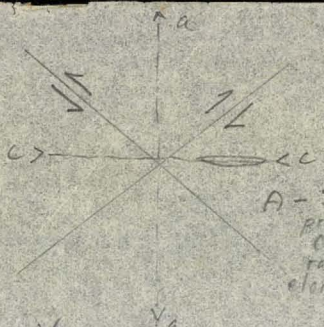
1. Grass Valley. The Sierra Nevada region in general appears to be a complicated one, but the Grass Valley district in itself seems relatively simple. The following notes are based on "Structural History of the Fracture Systems at Grass Valley, ~~Nevada~~ Calif., by W.D. Johnston and Ernst Cloos, Ec.Geol., Vol.XXIX,No.1,Jan.-Feb.,1934. 39-54

A body of granodiorite, 5 miles from north to south and 0.5 to 2 miles wide, invades a complex of sedimentary, metamorphic and igneous rocks. The granodiorite is homogeneous,and similar to the very large mass at Nevada City. The walls flare outward with depth,and the contacts are very sharp. Flow structure is nearly lacking; a few faint platy elements parallel the intrusive contact in the Empire mine. The granodiorite as exposed at Grass Valley is the top part of a large intrusive, as indicated by roof pendants exposed in underground workings;by the rapid downward widening, and by the relative scarcity of primary platy or linear flow structure. The sharp character of the contact and the absence of abundant xenoliths near the contact suggests that the intrusion grew by the slow pushing apart of the wall rocks. This Grass Valley cupola is thought to have passed from a state of viscosity to one of rigidity without great internal differential movement.

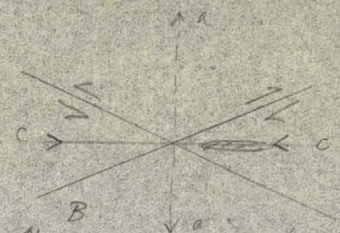
The plan and section show the fracture system. The crossing , striking NE,are nearly vertical,commonly without quartz filling,but often filled with pre-quartz basic dikes. The veins dip from 10 to 70°,averaging 35°. Their conjugate habit is well shown on the section.

Johnson and Cloos call the vein fractures marginal thrusts, and stress the parallelism with the north-south axis of the granodiorite. The section suggests strongly that these fractures are rather "Streckflaechen". (Balk, Structure Elements of Domes,Bull. Am.Ass.Petrol. Geol.,Vol.20,No.1,Jan., 1936. P.59,also Figs. 7 and 11) Johnson & Cloos call the NE crossings part of a regional joint system, and hence having nothing to do with the Grass Valley massive. ~~This may be so; but the map shows them limited to the vicinity of the intrusive, and they fit in well with the scheme advanced below, based on the supposition that the vein fractures are Streckflaechen and the crossings cross joints.~~

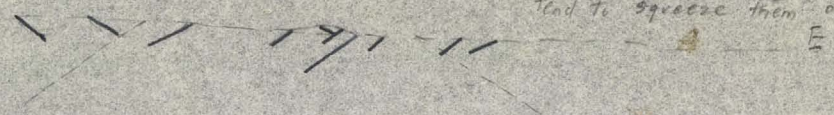
Balk (op.cit.) says that Streckflaechen are oriented more or less at random. The Grass Valley vein fractures show a decided irregularity of orientation,as a glance at the map shows. ~~Nevertheless, it looks from Balk's Fig.7 that a logical orientation of the Streckflaechen would be with strike~~



A – Shear Fractures produced by horiz. Compressing planes at rather small ∡ to direction of elongation. DIAGRAM



Horiz compression acting on flat Grass Valley vein fractures. Planes make large ∡ with aa; resistance along them would tend to squeeze them open.



Section

Outline Map, Grass Valley Quadrangle
After Lindgren

It is true that if the crossings are cross-joints of the Grass Valley intrusive, then they are not oriented correctly with respect to the supposed streckflaechen, since the latter, not far from normal in strike to the strike of the crossings, must have been originally tension faults, and the direction of compression, were the crossings cross-joints, must have been parallel to the latter. But the crossings are apparently regional in nature, hence they are probably not cross-joints of the Grass Valley massive. Since the measured displacements on the vein fractures are reverse in sense, i.e. the fractures are thrusts, it follows that if these fractures were originally Streckflaechen, they suffered a reversal of movement through compression which must have acted in a roughly horizontal direction. With moderate cover over the massive, a horizontal compressive stress would turn the vein fractures into reverse faults; the planes were there ready, offering lines of least resistance.

Consideration of the mineralization confirms this notion. For such extremely flat veins, a powerful component of stress acting to produce nearly vertical tension seems absolutely necessary. Horizontal compressive stress with easiest relief upwards would supply this. Note from the diagram that in the case supposed, the flatter the veins, the greater the tendency for them to be pulled open.

The geologic history as worked out by Johnson and Cloos will now be reviewed, to see whether any data confirming the notion outlined above can be found.

Geologic History.

1. Formation of the vein fractures. Note that H. Cloos and Balk say that the cross-joints are the earliest to form; the crossings, later than the vein-fractures, are therefore probably not cross-joints, but since the latter form also at an early stage. The vein fractures, localized as they appear to be more by the position of the top of the massive than by the sides of the massive, are assumed by the writer to be Streckflaechen. If so, they were at first normal faults.

2. Formation of the crossings, many soon occupied by basic dikes. While regional in nature, they are probably related to the Sierra Nevada complex batholith as a whole. Their attitude suggests regional compression, NE-SW, and the complementary aplite and basic dikes along them suggest a late phase of magmatic differentiation, not necessarily, however, connected with the Grass Valley intrusive itself. If NE compression did accompany the formation of these crossings, their vertical dips show that the stress was horizontal; and while the easiest relief in general was NW-SE, for the country as a whole, nevertheless, with a system of preexisting Streckflaechen, the tendency would be for the horizontal compression to shove up the hangingwalls of the Streckflaechen, giving a direction of elongation locally vertical, and pulling open these flat fractures.

3. Prior to the mineralization, the basic dikes of the crossings were offset along the vein fractures, in the reverse sense, maximum 20'. Since there were no markers in the granodiorite prior to the injection of the dikes, any original normal movement on the vein fractures would never be seen.

4. Intrusion of the aplite dikes along the crossings.

5. Aplites reverse faulted along vein fractures, and offset along some of the crossings.

6. Vein fractures, and a few of the crossings, filled with quartz.

7. Intermineral thrust movements along the vein fractures.

8. Renewed formation of crossings which offset the veins.

The last two stages go far to confirm the ideas set forth above, that is, they show thrusting on the vein fractures in close connection with whatever stress produced the crossings, since that stress operated before and after the thrusting. Incidentally, the paper mentions the fact that the vein fractures and the crossings are mutually intersecting fracture sets.

Summary- Whether the vein fractures were Streckflaechen or marginal thrusts is not of fundamental importance. The chief points brought out in the study are these:

1. The regional fracture pattern has two components: the crossings, regional on a great scale, but probably connected with the intrusion of the Sierra Nevada batholith, and the vein fractures, regional on a smaller scale, and whose environment and reason for existence was furnished by the Grass Valley granodiorite. Hence both types of regional fractures are probably connected with large scale intrusion; the vein fractures are certainly primary intrusion fractures, whatever their origin in detail.

2. The ability of important gold veins to form along extremely flat faults while thrusting was actually taking place along these planes. Elongation upward is almost the only conceivable mechanism for this.

3. Change in the direction of elongation due to preëxisting flat faults. The direction must have been NW-SE to permit the crossings to form, for these appear to be tension joints; and yet it must have been nearly vertical to permit the veins to form along the flat faults. The fact that no dikes, apparently, are found along the vein fractures, although reverse movement on these fractures took place between the intrusion of the basic and that of the aplite dikes, and after that of the aplite dikes, may of course mean that some outside factor changed the direction of elongation at about the time of the mineralization. This looks doubtful, because if the reverse movement on the vein fractures was straight up the dip, then the direction of elongation, for a conjugate set of reverse faults, must have been about vertical. The explanation probably lies in the fact that for such a solid thing as a dike, an actual opening was necessary, while with quartz and sulphides, a mere potential opening would suffice.

Note: In connection with the above conclusions, the descriptions of the veins fractures and crossings are of interest:

Veins: Not simple veins, but fracture zones of variable width and degree of shattering, within which the quartz veins are confined. Nearly flat HW and FW feather joints, connected with the reverse movement. Often, where very abundant, these are ladder links to a parallel quartz vein within the same vein zone

Crossings: Vertical joints, in places simple, in places sheeted zones. Some tight, others water courses; some have gouge. Many individual crossings are short, but locally some form relatively persistent zones. There is little displacement along either veins or crossings where they intersect, but offsets of both kinds do occur.

Note.

In connection with the possibility that the Grass Valley vein fractures were originally flat-lying normal faults or Streckflaechen, it is of interest to note that Balk, in "Structure Elements of Domes", says that at least a part of the Cobalt silver ores occur along flat-lying normal faults, near the lower contact of a diabase sill. The fissures are planes of expansion such as have been noted elsewhere near contact zones of diabases. Balk says also that in the Yankee Fork District, Idaho, two sets of fissure appear over an arch of volcanics 5 miles wide, underlain by a central volcanic mass. One set strikes NE, the other at right angles to it. Check this from original paper, in "Ore Deposits of the Western States", C.P.Ross: Ore Deposits of Idaho in Relation tp Structural and Historical Geology, p.270. Check also the possibility for synthetic and anithetic faults over intrusive centers, suggested by Balk for Bonanza, Colorado (USGS PP 169) and Parr ral (Schmitt, AIME Tech.Pub.304, 1930).

Further accessible references for study: Der Sierra-Nevada-Pluton in Californien (1935) by E. Cloos. Mother Lode and Sierra Nevada Batholith, E.Cloos, 1935. Gold Quartz Veinsof the Alleghany District, by Ferguson. USGS PP 172, 1932.