THE CORRELATION OF FRACTURE SYSTEMS AND THE EVIDENCES OF PLANETARY DISLOCATIONS WITHIN THE EARTH'S CRUST.

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In a recent paper the author has attempted to correlate within a complex and varied geological province the somewhat scanty observations which deal with the orientation of fracture systems.[1] The results of this correlation possess considerable significance inasmuch as there is a clear indication that over quite an appreciable fraction of the earth's surface the main lines of fracture betray evidences of a common origin. Since the publication of the paper so many verifications of this conclusion have come to the writer from geologists whose work was unpublished, or which apply to the extension of the province treated, that it seems desirable to extend both the area considered and the general topic in order to include the new material.

That the fracture systems observed in a local district betray close relationship to those of neighboring districts, was early shown by Phillips[2] and Haughton,[3] and later by Kinahan[4] for

[1] Lineaments of the Atlantic Border Region. Bull. Geol. Soc. Am., Vol. 15, Nov. 1904, pp. 483–506. Pls. 45–47. Read by title before the International Geographical Congress at St. Louis, Sept., 1904.

[2] Phillips, John. Illustrations of the Geology of Yorkshire, Part 2. The Mountain Limestone District. London, 1836, pp. 90–98. Also, Manual of Geology, London, 1885 (Etheridge and Seeley Edition), pp. 33–34.

[3] Haughton, Samuel. "On the physical structure of the old red sandstone of the County of Waterford, considered with relation to cleavage, joint surfaces and faults. Trans. Roy. Soc. Lond., Vol. 148, 1858, pp. 133–348. Also, On the joint systems of Ireland and Cornwall and their mechanical origin. Ibid, Vol. 154, 1864, pp. 383–411.

[4] Kinahan, Gerald Henry. Valleys, their relations to fissures, fractures and faults. London, 1875, pp. xiv and 240.

portions of the British Isles, and also by Kjerulf[1] for Norway. Haughton, and more recently Brögger,[2] have conclusively proven that in the districts which they studied the normal faults conform in direction to the general system of joints; but the importance of this result, though reinforced and emphasized by Daubrée,[3] has never been fully appreciated.

For the region of the eastern United States it was developed in the author's paper referred to, that the joints and normal faults of greatest prominence follow in any particular part of the province one or more of three or four general directions. These directions approximate to the meridian and the equator, and to diagonal intermediate bearings. There seems good reason to believe that as regards the first two of the directions mentioned the approximations to meridian and equator are fairly close—generally within 5 degrees. As regards the intermediate directions this is far from being the case, and there are in general not two but several intermediate directions; yet their general tendency to occupy rather distinctly intermediate positions between the meridian and the equator is sufficiently manifest. Wherever close observations have been made it has been found that not four but a considerably larger number of directions may be made out, as will be clearly indicated in the following tables.

These observations receive, moreover, strong support from the studies of Green, Prinz, and others dealing with the orientation of the broader earth features upon the entire planet.

North Carolina.—Since the author's paper[4] was published it was learned that a careful measurement of joint and dike directions had been made by Mr. F. B. Laney within the Newark area of North Carolina, and as a result of his studies Mr. Laney stated that joints and dikes alike were oriented mainly north and south, east and west, northwest and southeast, and northeast and southwest. Mr. Laney has kindly turned over to the author his

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[1] Kjerulf, Theodor. Die Geologie des südlichen und mittleren Norwegen. Authorized German edition by Gurlt. Bonn, 1880, pp. 1–350.

[2] Brögger, W. C. Spaltenverwerfungen in the Gegend Langesundskien, Nyt Magazin for Naturvidenskaberne. Vol. 28, 1884, pp. 253–419, with map.

[3] Daubrée, Géologie experimentale. Vol. I, pp. 289-385.

[4] l. c.

detailed observations, from which it is clearly seen that the intermediate directions which have greatest importance, while properly enough described in general terms as northeast and northwest, fall principally in six and not two series. The comparison of the general results determined for the lineaments of the Atlantic border region with the general directions observed in individual districts examined by the writer expresses a like result. The actual observations made by Mr. Laney have been tabulated by the author with the following result.

N 30° W 14	N–S 7	N 15° E 62
N 30°–40° W 1		N 30° E 9
N 30°–35° W 3		N 35° E 2
N 35° W 1		N 40°–50° E 1
N 40° W 1		N 45° E 8
N 45° W 2		N 50° E 1
N 50° W 2		N 55° E 2
N 55° W 2		
N 55° W 1		N 60° E 12
N 60° W 10		N 65° E 1
N 65° W 1	E–W 8	N 80° E 1

In the North Carolina Newark both joints and dikes stand approximately vertical, and it appears that the dominant direction is N 15° E. The remaining joint series are so oriented as to fall into three conjugate sets.. Moreover, the joints observed at any locality were found generally to be in pairs corresponding to one or the other of the sets.

The Finger Lakes district of West-Central New York. Mr. Charles G. Brown of Ithaca, N. Y., has measured the directions of more than 1000 joint planes which occur in the vicinity of Ithaca in the basins of the near-lying lakes. In order of relative numerical importance the joint directions of the district are found to be:[1]

N. 20° W. (288), N. 10° W. (139), N. 70°—75° E. (131), N. 15°—16° W. (88), N. 60° W. (86), N. 30° E. (68), N. 80° E. (62), N. 40° W. (51), N. 4°—6° W. (43), N. 30°—34° W. (35), N. 85° E. (35), and N.—S. (15). These twelve directions include 941 of the 1,004 measurements and with the exception of

[1] Jour. Geol., vol. 13, 1905, pp. 367–374.

the direction N. 12° W., whose 14 observations should perhaps be added to the 139 directed N. 10° W., no other direction is represented by more than six measurements.

The fracture system of which these are the more prominent series has controlled in an important way the topography of the region, as has been described in the paper referred to.

The larger basin of the near lying Lake Ontario has been shown by Wilson[1] to have its lines of drainage determined by fracture planes, though no indication is afforded of the cardinal directions characteristic of the system. This author says:[2] "The direction of the master joint fractures is intimately associated with the trend of all the master valleys, though the modern post-Glacial channels are independent of them. . . These master joints with other associated valleys and the parallel system of valleys of similar trend on the adjacent Archean areas are probably associated with an extensive system of faults of pre-Ordovician date."

This province like that surrounding the Ausable chasm near Lake Champlain should afford a most promising field for the observation of cardinal directions within fracture systems.

The French River District of Ontario.—Bell has called attention to the marked orientation of the inlets and streams within the French River district of Ontario,[3] and has ascribed this orientation to the control by fissures, joints, and dislocations. The directions are strongly marked in the district and trend E–W or very nearly so, and approximately NW–SE, NE–SW. Bell says:

"The effects of cleavage and bedding, fissures and joints, rock-crushing, dislocations, intrusive dikes, etc., on the production of geographical features are here so well marked as to make it worth calling attention to some points in connection with this subject. In any part of the district we may select, it will be found that the joints, fissures, and dislocations, generally run in two sets intersecting each other at large angles, but those of

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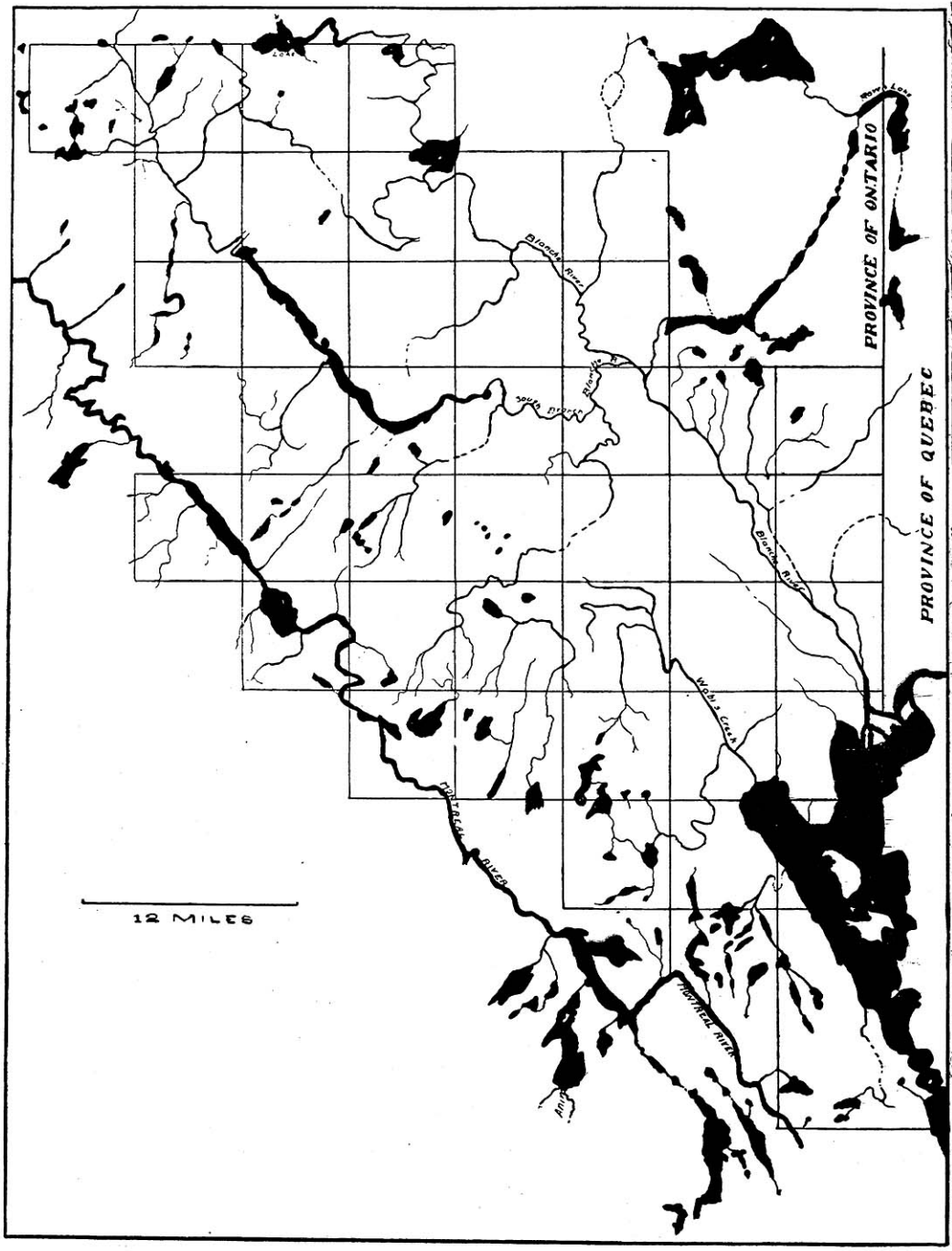
1 Wilson, A. W. G., Trent River system and St. Lawrence outlet. Bull. Geol. Soc. Am., Vol. 15, pp. 211–242. Pls. 5–10.

2 Bell, Robert. Report on the geology of the French River district, Ontario. Geol. Surv. Can., Ann. Rept., N. S., Vol ix, 1896, pp. 20–I to 21–I.


PROVINCE OF ONTARIO
PROVINCE OF QUEBEC
Blanche River
Blanche River
Blanche River
Wabi's Creek
Frederick River
Frederick River
12 MILES

either set are parallel to each other. Usually one set is more strongly marked than the other and exercises an important influence in the decay and disintegration of the rocks, and this in its turn affects the contours of hill and valley and determines the positions of streams, inland lakes and of the inlets, etc., of Georgian Bay.

"The dikes which traverse both the Laurentian and Huronian rocks of the district and the fissures and lines of crushing which occur more particularly in the former, have given birth to some of the more striking features of the map. . ."

In an earlier paper Bell[1] had already shown that many of the long and straight valleys within the Archean area of Canada now occupied by rivers, lakes, or by inlets of the larger lakes, have been formed as a result either of the relatively rapid decay on dikes or on lines of close joints. The valleys now occupied by water are further extended by valleys filled in with drift. Examples are Onaping Lake, 30 miles long; Long Lake, 52 miles in length; and Sepiwesk Lake, which with Nelson River forms a trench 96 miles in length. The Mattagami River is thus guided for 160 miles, and Lake Temiscaming, 35 miles in length, with Deep River, forms a rectilinear trench in places more than 2000 feet in depth. Soundings show that the rectilinear inlets of Georgian Bay are extended lakeward by straight channels at their fronts. The prevailing joints of the region correspond perfectly in direction with these trenches.[2]

The map just published[3] by the Department of Crown Lands and covering the area about Lake Temiscaming reveals this orientation in great perfection (see Plate III). Dr. C. K. Leith, who has done much recent geological work in the district confirms the general correctness of this map and the correspondence of drainage lines with the direction of the prevailing joints. As the map indicates, the prevailing joint direction is about N. 40° W., with N. 50° E., and N–S the directions next in importance.

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[1] Bell, Robert. Pre-Paleozoic decay of crystalline rocks north of Lake Huron. Bull. Geol. Soc. Am., Vol. 5, 1894, pp. 357–366, Pls, 15, 16.

[2] Personal communication from Dr. Bell.

[3] Map of part of the District of Nipissing, showing agricultural lands surveyed on Lake Temiscaming, Ontario, 1905.

Southwestern Wisconsin and Northern Illinois.—As early as 1866 Whitney[1] showed that the Galena limestone formation is intersected by two sets of vertical fissures whose directions are approximately east and west, and north and south.

"All through the mining district, indeed, in Wisconsin and Iowa as well as in Illinois, the heaviest diggings will usually be found on crevices varying but little from east to west in their general direction. . . The norths and souths on the other hand or those crevices which have a course approximating to the meridian, are much less important, although these in some instances are the most productive ones of portions of the lead region." Buckley as a result of his measurement of joint directions within the quarries of the State of Wisconsin makes the following general statement.

"As will be seen in the accompanying map the joints of the sedimentary rocks strike in four main directions. The prevailing general direction of the joints is northeast and southwest. The other directions are northwest and southeast, east and west, and north and south."

An examination of Buckley's map will show that the intermediate directions vary in many cases widely from the forty-five degree positions. Under the writer's direction Mr. E. C. Harder[2] has made a careful study of the joint systems which are developed in the rocks of southwestern Wisconsin. For this province as a whole he finds that in order of numerical superiority the dominant joint directions of the district are, N. 35° E., N. 75° E., N. 35° W., N. 55° W., N. 45° E., N. 85–90° E., N. 25° W., N. 45° W., N. 15° W., N. 25° E., N. 65° E., N. 75° W., N. 65° W., and N. 55° E. The tendency of the five degree interval to appear is noticeable and indicates that here as elsewhere the observations of slightly curving planes become adjusted to the larger unit of the compass. Thus the equatorial direction, which is the dominant one, should probably include the measurements ranging between N. 85° W. and N. 85° E., or 25 in all. Only less noticeable aggregations appear elsewhere in the table, where

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[1] Whitney, J. D. Geology of the Lead Region. Geol. Surv. Ills., Vol. 1, 1866, p. 194.

[2] Jour. Geol. Vol. 13, 1905, pp. 363–366.

probably if the joints could be measured with greater accuracy they would fall between two five degree limits on the side of the one having the numerical superiority.

Iowa.—McGee[1] has called attention to the conjugate set of joints which penetrate the quarry rocks of the State of Iowa. Of these joints there are two classes recognized, which are designated by the quarrymen as "clay seams" and "dry seams." The chief set consists of two series of "clay seams" crossing each other approximately at right angles, with two series of "dry seams" also crossing about at right angles and approximately bisecting the angles formed by the principal series. He further adds:

"The phases presented are, however, variable. Either of the two classes or either system of either class may be absent, or additional and generally less conspicuous systems . . . sometimes so blended with the predominant class as to separate the strata into either irregular or tolerably regular polygonal blocks . . . may be introduced; and the two classes pass imperceptibly into each other."

In a personal letter Dr. McGee adds:

"Unhappily my memory is not as clear as I could wish; so far as I am able to recall the less distinct double-sets are orthogonal, departing a few degrees from N–S and E–W, though the direction of the departure from the meridian and parallel escapes me. The more prevalent and conspicuous double-sets are also orthogonal or nearly so and approximately NW–SE, and NE–SW. So nearly as I can recollect the minor and major double-sets do not exactly divide the quadrangle. The difference is somewhat more (or less) than 45°; . . .

"As I dwell on the matter in this writing the impression revives that the dominant single-set trends about N. 55° W., and S. 55° E., with the correlative orthogonal single-set about N. 35° E., and S. 35° W.; and that the stronger joints of the minor double-set trends about N. 5° W. to S. 5° E., and the weaker one about N. 85° E. to S. 85° W. In any event such a scheme will

[1] McGee, W. J., Note on jointed structure. Am. Jour. Sci. 3rd Ser. Vol. 25, 1883, pp. 152–155.

illustrate approximately the relation of the joints worked out in my building-stone researches in 1880. My best examples were found in the central and southern sections of the state."

Arkansas.—Professor Branner[1] has been good enough to call the author's attention to similar results obtained by Professor Newsom and himself when studying the eastern portion of the Boston Mountains in Arkansas, in which investigation the peculiarities of drainage, the parallelism of streams, the similarity of their elbows, and the relation of these streams to structural features in the adjoining regions were put upon record. The dominant directions of drainage are NE–SW, and NW–SE. With greater definiteness these directions are given as N. 60°–67° E., and N. 51°–65° W. The NE–SW series seems to be controlled by the monoclinal folds. Attention is called, however, to the relationship existing between these stream directions and a series of dislocations in the province, and it is further stated that "there are two other systems of joints in the area here especially considered, one running N. and S., the other E. and W."

The Great Basin of the Western United States.—Since the publication of the early reports upon the geology of the Great Basin of the western United States it has been generally recognized that the dominant faults trend near the meridian. Gilbert has also called attention to the fact that formations rather generally end abruptly on east and west lines. Spurr[1] in his general conclusions upon the origin of the basin ranges of Nevada and California says:

"The faulting in general seems to be about as frequent as in other regions which show the same amount of folding. The chief faults belong to the north-and-south and east- and-west systems. There are also diagonal ones running northeast and northwest and in each of the systems they may have a very great displacement."

The most important directions described by Spurr are in per-

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[1]Newsom, J. F., and Branner, J. C. The Red River and Clinton Monoclines. Am. Geol., Vol. 20, pp. 1–13.

[2]Spurr, J. E. Origin and Structure of the Basin Ranges. Bull Geol. Soc. Am., Vol. 12, 1901, pp. 217–270. Pls. 20–25.

fect accord with those described by Gilbert as occurring in the clays of Lake Bonneville and controlling the local drainage directions. The data were secured by Mr. Israel C. Russell, then his assistant, of whom Gilbert[2] says:

"He found that the details of drainage were controlled by a compound and extended system of joints. The principal series trend almost precisely north and south and the subordinate series east and west. They are all vertical and straight and (within each series) closely parallel. They are readily traced from top to bottom of the walls of the lateral ravines and not infrequently a wall exposes a broad flat sheet face caused by the removal of the clay from one side of the plane of jointing. Elsewhere the faces of the bluffs are buttressed by square pilasters or ornamented by outstanding rectangular columns, the forms of which have been determined by the two systems of joints . . .

"The point of especial interest is that these joints have been developed in post-glacial time within the series of strata not perceptibly indurated and which repose undisturbed in the place where they were deposited. The strata are nearly horizontal and their inclination of less than ½° northward is presumably the pitch slope of the bottom upon which they were thrown down."

Similar joints were observed by Russell[1] in the clays of Lake Lahontan. He says:

"The marly clays forming the upper and lower members of the Lahontan series usually break into prismatic and cubical blocks on weathering; the vertical faces of the blocks are determined by joint planes and the horizontal by planes of lamination. In many localities a more pronounced jointing occurs, forming two approximately vertical systems that are nearly at right angles to each other. Judging from the number of in-

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[1]Gilbert, G. K. Post-Glacial Joints. Am. Journ. Sci., 3rd Ser., Vol. 23, 1882, pp. 25–27. See also same author, Lake Bonneville. Monograph I, U. S. Geol. Surv., 1890, pp. 211–213.

[2]Russell, I. C. Geological History of Lake Lahontan. Monograph XI, U. S. Geol. Surv., 1885, pp. 162–163.

[1]Iddings, Jos. P. A Fracture Valley System. Journal of Geology, Vol. 12, 1904, pp. 94–105. Pl.

stances observed at widely separated localities, the joints in question may be traced through the entire series of Lacustrian beds."

Yellowstone National Park.—Quite recently Iddings[2] has shown that upon the Livingstone quadrangle, which is included in the area of the Yellowstone National Park, a net-work of faults has determined a fracture valley system in which the dominant directions are NE–SW, NW–SE, N–S, and E–W. More definitely the diagonal directions are given as N. 30° E., and N. 60° W. He says:

"A study of the topographical map reveals the angular character of much of the drainage system, and the prevalence of certain parallel and sub-parallel lines which appear in various streams and occur in quite diverse portions of their channels. Along parallel lines different streams may be flowing in opposite directions: . . . The persistency of these lines becomes more striking when the geological structure of the region is taken into account and it is observed that certain drainage lines traverse rocks of such diverse nature as gneiss, schist, volcanic tuff, breccia, solid lava, limestone, sandstone, and shales.

"The relation of some of these directions of drainage to known fracture planes will be pointed out. The dominant drainage lines in the southern three-fourths of the quadrangle trend about NE–SW, and NW–SE, more nearly N. 30° E. and W. 30° N., the angle between them being approximately 90 degrees. There are other systems of almost rectangular lines somewhat differently oriented, namely, N–S and E–W."

Other Districts.—Only less important in a study of the orientation of fracture systems are other studies which will not be here specifically referred to except as they have been included in the following table. To facilitate the study of directions there are given in separate columns: 1st. Those bearings of fracture systems which approach the direction of the meridian; 2nd. Those which approach the direction of the equator; 3rd. Those which occupy intermediate positions within the quadrants NE and NW; 4th. Those which occupy intermediate positions in the quadrants NW and SE.

TABULATION OF FRACTURE SYSTEMS FOR THE UNITED STATES.

(Partial.)

Bearing of Fracture Series.

DISTRICT AND AUTHORITY.	Meridional or nearly so.	Equatorial or nearly so.	In quadrants NE & SW.	In quadrants NW & SE.	Remarks.
Great Basin of Western United States.					
General direction for Gt. Basin.—Gilbert.	N—S	.....	.....	.....	Formations also end in E—W cliffs.
Basin Ranges in California and Nevada.—Spurr.	N—S	E—W	NE—SW	NW—SE	
Upper Sevier Basin.—Gilbert.	.....	.....	N 10°—30° E	.....	
Utah and Arizona.—Gilbert.	N—S	.....	.....	.....	
General Direction in Colorado plateau —Gilbert.	N—S	.....	.....	.....	
Lake Bonneville (Old River Valley.)—Gilbert.	N—S	E—W	.....	.....	In clay.
Lake Lahontan.—Russell.	N—S	.....	.....	.....	Also a perpendicular vertical set in clay.
Lake Lahontan (N. of 37° lat.)—Russell.	.....	.....	N NE—S SW	.....	
Telluride quadrangle in Colo.—Purington.	.....	.....	N 38° E N 53°—63° E	N 21°—51° W N 87° W	Directions N 53°—63° E and N 21°—51° W recognized as each containing several series.
Rico Mts. in Colo.—Ransome.	.....	.....	N 25°—65° E	N—N 45° W	
Globe Quadrangle in Arizona—Ransome.	.....	.....	NE—SW	NW—SE	
Bisbee Quadrangle in Arizona.—Ransome.	N—S	E—W	NE—SW	NW—SE to W NW —E NE	Also some others less common.
Albuquerque and Magdalena Mts. in New Mexico.—D. W. Johnson.	N—S	E—W?	.....	.....	
Same.—Keyes.	N—S	.....	.....	.....	These are the directions of major faults in modern mts.
Death Valley in So. Cal. —Campbell.	N—S	.....	NE—SW	.....	
Boise Quadrangle, Idaho —Lindgren	.....	E—W	E NE—W SW	.....	Rarely NE—SW.
Livingston Quadrangle, Montana.—Iddings.	N—S	E—W	N 30° E	N 60° W	
Butte Min. District.—Emmons & Tower.	.....	Mainly near E—W.	.....	.....	In quadrant between NE and SE but mainly near E—W. "Secondary fractures" with dips from 45°—65° at right angles to mineral veins.

TABULATION OF FRACTURE SYSTEMS FOR THE UNITED STATES—Continued.

DISTRICT AND AUTHORITY.	Meridional or nearly so.	Equatorial or nearly so.	In quadrants NE & SW.	In quadrants NW & SE.	Remarks.
High Sierra of California.—Becker.	.....	.....	E NE—W SW	N NW—S SE	Two diagonal sets sometimes found striking between N—S and NW—SE, and dipping 45° either way. Also rarely horizontal sets.
Same. Upper Kern Valley.—Lawson.	N—S	.....	.....	.....	
Lower Mississippi Valley.					
Boston Mts. in Arkansas.—Branner-Newsom.	N—S	E—W	NE—SW	NW—SE	
Ozark Mts. in Ark.—Powell.	N—S?	.....	.....	.....	
Brunswick Dist. in Indian Territory.—Eldridge.	.....	.....	.....	N 20° W N 50° W	Other directions of minor importance.
Balcones Fault Zone in Texas.—Hill & Vaughan.	.....	.....	N of E—S of W	.....	Also minor faults.
Uvalde Quadrangle in Texas.—Vaughan.	.....	.....	NE—SW	NW—SE	
Upper Mississippi Valley.					
Entire State of Wisconsin.—Buckley.	N—S	E—W	NE—SW	NW—SE	Main direction NE—SW.
So. Wisconsin—Percival.	.....	N 85° E N 85° W	.....	NW—SE N 70° W N 80° W	
SW Wisconsin.—Harder.	N 5° E	E—W N 85° W N 85° E	N 35° E N 45° E N 50° E N 55° E N 65° E N 75° E	N 25° W N 35° W N 45° W N 55° W	
Entire State of Iowa.—McGee.	N 5° W circa.	N 85° E circa	N 35° E circa	N 55° W circa	Form two rectangular sets.
Eastern Iowa.—Bain and Calvin.	N—S	Nearly E—W	.....	.....	Main direction E—W A third series is mentioned at 45° to others.
Northern Illinois. (Also Southwestern Wisconsin.)—Whitney.	N—S	E—W	.....	.....	
Rosiclare Dist. in So. Ill.—Emmons.	.....	.....	N 25° E N 32° E N 50° — 57° E	.....	Not sufficient number of planes observed to clearly indicate these as series.
Minnesota.—Upham.	N—S	E—W	N 60° E	N 45 W	Scattered observations.
Eastern United States.					
So Conn. Valley in Conn.—Davis.	N—S (nearly.)	.....	N 30° — 45° E	N 20°— 30° W	Directions taken from map.
Conn. Valley in Mass.—Emerson.	N—S	.....	N 10°— 15° E N 20° E N 20°— 30° E	N 50° W	Values are approximate only and taken from map.

TABULATION OF FRACTURE SYSTEMS FOR THE UNITED STATES—Continued.

DISTRICT AND AUTHORITY.	Meridional or nearly so.	Equatorial or nearly so.	In quadrants NE & SW.	In quadrants NW & SE.	Remarks.
Pomperaug Valley in Conn.—Hobbs.	N 5° W	N 90° E	N 15° E N 33° E N 55° E	N 34° W N 44° W N 61° W	Unusual directions are, N 20° E, N 25° W. The main directions are the four—N 5° W, N 15° E, N. 34° W, and N 55° E.
River System of State of Conn.—Hobbs.	N. 5° E (eastern upl'nds.) N 5° W (western upl'nds.)	N 90° E	N 15° E N 33° E	N 44° W	Of secondary importance also N 48° E, N 20° E.
Five areas distributed from Stockbridge, Mass. to N. Y.—Hobbs.	N 5° E	N 90° E	N 15° E N 33°—35° E N 50°—55° E N 68°—70° E	N 34°—35° W N 60 W	Both joints and lineaments follow these directions.
Boston Basin—Crosby.	N—S	E—W	... .	.....	Dikes take same directions.
Cape Ann.—Shaler.	N—N 5° W.	N 90° E	N 30°—40° E N 45°—50° E (N 75°—80° E)	N 20°—25° W N 30°—35° W	Less important direction between N 10° E and N. 30° E.
White Mt. Notches and River System.—Hobbs.	N 4° E N 5° W	N 90° E	N 12° E N 16° E N 36° E	N 20° W N 25° W N 35° W	In part strong hydrographic lines with few important representatives.
Adirondacks and Lake Champlain. Northern section.—Cushing.	N—S circa	E—W circa	N 45° E circa	N 45° W circa	
North Hudson Dist. in Adirondacks.—Kemp.	N—S	.....	NE—SW	NW—SE	Also other directions. See Bull. Geol. Soc. Am., Vol. 15, pl. 47.
Cayuga Lake Basin.—Brown.	N—S N 4°—6° W	N 85° E	N 15°—16° E N 30° E N 70°—75° E N 80° E	N 10° W N 30°—34 W N 40° W N 60° W	Also personal communication.
French Riv. Dist. of Ontario.—Bell.	.....	E—W	NE—SW	NW—SE	
Triassic area of N. Carolina.—Laney.	N—S	E—W	N 15° E N 30° E N 45° E N 60° E	N 30° W N 60° W	Directions in part of dikes and in part of joints.
Dominant lineaments of Atlantic border region.—Hobbs.	N 5° E	.....	N 50° E	N 33° W N 43° W	Other lineaments directed N 30° E, N 85° W, N 75° W and E—W.

In the above table have been included all reports which have come under the eye of the writer, or have been communicated to him personally, in which the orientation of the fracture systems has been indicated, however crudely; and this entirely without reference to whether the results favor one theory more than another. One condition only has been imposed, namely, that the fracture systems described shall be made up of individual surfaces that in steepness approach the vertical—are in general steeper than 70°—thus insuring that such tilting as may have occurred since their formation has not materially affected the plan of their arrangement.

There are undoubtedly many districts in which no such regularity of arrangement of fracture series can be discovered, but it will generally be found that the planes of jointing or of veins or dikes, are many of them inclined at comparatively low angles to the horizontal. Even where this is not the case, the number of directions of joint planes may be so many that no law of arrangement is discernable; as might well be true when the belt of rocks has been subjected to successive deformation within the zone of fracture either from a single or from several directions. If we are to discover any laws governing the orientation of fracture systems, it will be by proceeding from the simple to the more complex areas, and there is ample ground for assuming that where belts of flat-lying, homogeneous rocks without pre-existing fracture planes are deformed within the zone of fracture, there is normally produced a vertical prismatic system composed of intersecting parallel series. Moreover, observations would appear to show that even where rocks are far from homogeneous and lie in other than horizontal positions, an approximation to this result still obtains. While it has not as yet been demonstrated by experimentation, it is difficult to avoid the conclusion based upon field observation, that a second deformation of rocks which are already possessed of a simple prismatic system of joints through renewal of compression from the original direction, in the main merely increases the number of series within the vertical joint system.

It is certainly of much significance that the systems of fractures which are developed throughout the area of the United

States should so clearly correspond with the orientation of the grander features of the planet as they have been worked out in the studies of Prinz[1] and others. Prinz has found that the major features of the earth are arranged in two nearly rectilinear series running northwest and southeast, and northeast and southwest, with an intermediate series directed nearly along the meridian. It is evident that the present study merely blazes the way for a more thorough and careful correlation to be made when the available data are more nearly adequate for the solution of the problem. It is therefore hoped that geologists will co-operate to the extent of measuring and recording the direction of joint and fault planes within the districts which they individually have opportunity to examine.

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Madison, Wisconsin,
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[1] Prinz, W. Sur les similitudes que présentent les cartes terrestre et planetaires (Torsion apparent des planètes.) Ann. de l'observatoire royale de Bruxelles, 58th year, 1891, pp. 304–337.