Joint orientation measurements in Western Alberta and British Columbia

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Received on March 27th, 1981

Abstract

Joint orientations were measured in the mountains of Western Alberta and British Columbia. These were then evaluated statistically according to the standard method of Kohlbeck and Scheidegger. If the bisectrices of the preferred joint orientations are interpreted as principal directions of the neotectonic stress field, the maximum compression in the latter is found to be from NE-SW (in the South) to NNE-SSW (in the North). This agrees well with data regarding the neotectonic intraplate stresses observed from oil-well break-out data.

Riassunto

Gli orientamenti di una dislocazione sono stati misurati nelle montagne dell'Alberta occidentale e della Columbia Britannica. Questi furono quindi

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valutati statisticamente secondo il metodo standard di Kohlbrok e Scheidegger. Se le bisettrici degli orientamenti della dislocazione prescelta sono interpretate come direzioni principali del campo di stress neotettonico, la compressione massima andrà da NE-SW (nel Sud) a NNE-SSW (nel Nord). Questo si accorda bene con i dati concernenti gli stresses neotettonici osservati dai dati di pozzi petroliferi aperti.

1. Introduction

During the summer of 1980, a campaign of joint orientation measurements was undertaken in Western Alberta and in British Columbia. Essentially, the measurements were taken along highways forming a circle tour from Edmonton to Rocky Mountain House, the Kananaskis Valley, Crowsnest, Kelowna, Williams Lake, Bella Coola, Prince George, Grande Prairie and back to Edmonton.

The geology of the region runs the gamut from various sediments to batholiths. In the interior of British Columbia, along the Bella Coola road, large Tertiary lava and ash regions were encountered. As is usual in joint-orientation studies, no correlation of the orientations of the steeply dipping joints with lithology was observed. These points therefore, are to be interpreted as of tectonic origin, the most likely assumption being that they are some form of a shear phenomenon in a triaxial stress field (Scheidegger, 1979).

2. Methodology

The method of taking the measurements and of evaluating them was that described by Kohlbeck and Scheidegger (1977). Accordingly, care was taken to measure only fresh, smooth joints in manifestly recent outcrops (mainly road cuts). Generally, in one "location", about 3 autocrops 3 - 8 km apart (if possible) were investigated, in each of which some 20 orientation measurements were made. The statistical evaluation consisted in fitting 2 or 3 superposed distributions of the type exp (k cos^2 θ) to the data. The best-fitting distributions were calculated by a functionminimization procedure described by Kohlbeck and Scheidegger (1977) using the University of Alberta Computing facilities. This yields the 2 or 3 best fitting, "preferred" orientations of the joints, including error limits, in the "locations" in question. Whether 2 or 3 distributions were necessary for obtaining a fit, was inherent in the data of each "location".

3. Results

All in all, 23 "locations", involving 62 individual outcrops, were investigated. The 23 "locations" have been numbered from 1 to 23; the results of the evaluations are shown in Table 1, using standard notation. Thus, the first column gives the "location", the second the number of joints in that "location", the next 3 columns the orientation of the best-fitting distributions (azimuth NE of dip direction/dip, with 10% - confidence limits) then the angle between the first two orientations, and finally the bisectrix-direction of the smaller and of the larger quadrant. According to theory, the former may be interpreted as maximum, the latter as minimum compression direction in a triaxial stress field producing the joints.

For easier visualization, the strikes of the preferred joint-orientations and the projections of the two principal stress directions (as calculated above) have been plotted at their proper locations on a map (Fig. 1); the maximum compression has been indicated by a heavier arrow than the minimum compression.

An ispection of Table 1 and Fig. 1 immediately shows the following features:

The vast majority of "locations" show one principal stress direction (usually the maximum compression) in the NE-SW quadrant. The exceptions are the "anomalous" locations 1, 2 11 and 14. The mean value for the azimuth of the NE-directed principal stress in "non-anomalous" locations is N 24°E. According to one possible interpretation, this should be the mean value for the azimuth of the intraplate stress in the area. It is roughly normal to the Rocky Mountain Front.

TABLE I

ROCKY MOUNTAINS (TRUE NORTH)

Location	No.	Max. 1	Max. 2	Max. 3	Angle	P	T
1. Abraham Lake	84	310 ± 7/88 ± 7	42 ± 6/88 ± 4	—	88	176/3	86/1
2. Columbia Icefield	66	299 ± 5/86 ± 4	35 ± 9/85 ± 6	—	85	167/6	77/0
3. Kananaskis	64	242 ± 6/80 ± 4	321 ± 12/78 ± 7	204 ± 31/88 ± 40	78	193/1	102/14
4. Highwood Pass	88	102 ± 13/78 ± 9	1 ± 2/80 ± 8	—	81	231/16	302/1
5. Coleman	51	291 ± 25/90 ± 19	9 ± 14/84 ± 11	—	78	240/5	150/4
6. Fernie	56	255 ± 18/90 ± 10	159 ± 9/78 ± 5	—	84	28/9	297/8
7. Moyie Lake	63	237 ± 11/86 ± 6	320 ± 17/86 ± 14	—	83	8/1	98/5
8. Creston	66	88 ± 22/80 ± 8	341 ± 13/80 ± 13	52 ± 15/78 ± 14	75	215/17	125/0
9. Castlegar	63	271 ± 4/85 ± 5	2 ± 7/81 ± 3	—	90	227/2	136/10
10. Grand Forks	64	88 ± 11/87 ± 8	350 ± 14/88 ± 13	—	82	219/3	309/1
11. Carmi	63	52 ± 10/82 ± 6	310 ± 19/88 ± 12	—	78	180/8	271/4
12. Brenda Mines	63	236 ± 13/88 ± 6	328 ± 18/84 ± 14	25 ± 4/81 ± 5	88	102/5	192/3
13. Merritt	56	55 ± 15/85 ± 10	316 ± 8/82 ± 5	—	82	186/10	95/2
14. Clinton	63	299 ± 17/89 ± 18	207 ± 11/90 ± 14	—	88	73/1	163/1
15. Williams Lake	65	242 ± 14/76 ± 8	138 ± 10/88 ± 8	—	76	9/12	101/8
16. Tweedsmuir Pk	63	268 ± 9/79 ± 9	343 ± 14/84 ± 12	43 ± 13/85 ± 10	74	35/4	126/11
17. Bella Coola	42	61 ± 13/89 ± 19	338 ± 13/89 ± 20	—	83	289/0	199/2
18. Kleena Kleene	21	64 ± 14/66 ± 24	169 ± 17/82 ± 13	—	80	300/25	205/10
19. Alexis Creek	21	251 ± 16/84 ± 12	330 ± 12/80 ± 8	—	79	201/3	110/10
20. Quesnel	45	250 ± 13/81 ± 6	138 ± 8/90 ± 10	183 ± 15/76 ± 14	68	14/8	104/5
21. MacLeod Lake	51	51 ± 6/88 ± 2	143 ± 6/82 ± 4	—	89	276/7	7/4
22. Lemoray	64	68 ± 1/87 ± 6	324 ± 13/79 ± 25	—	76	197/11	106/5
23. Pine River Crossing	21	61 ± 13/90 ± 13	327 ± 3/87 ± 16	—	86	194/3	104/2

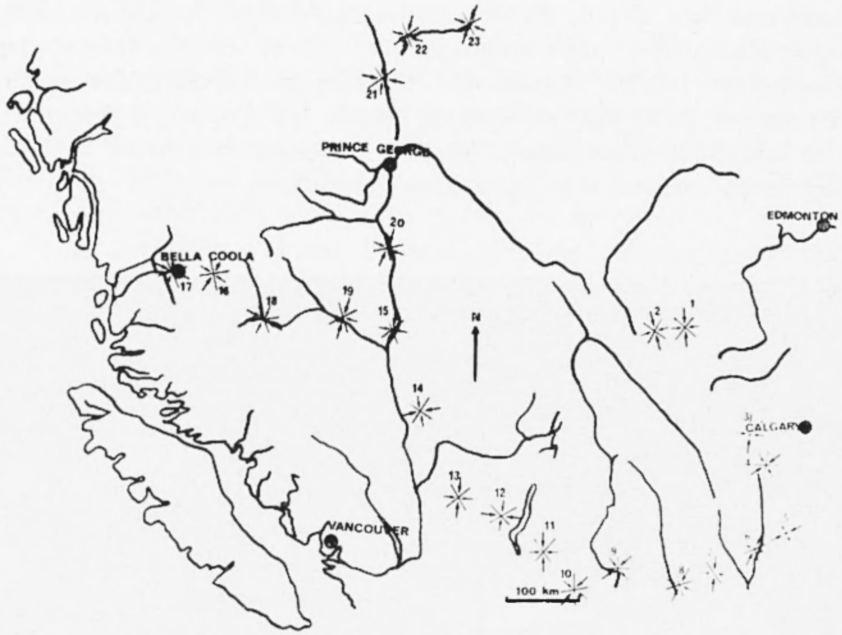

Fig. 1 - Preferred joint strikes and principal stress direction calculated therefrom for 23 "locations" in the mountains of Alberta and British Columbia.

It may be noted that there appear to be slight systematic variations in the preferred orientations of the joints (and stresses). Thus, at the locations farthest South (3 through 10), the mean azimuth of the hypothetical P-direction is close to N 45°E. In the remainder (excluding the "anomalous" locations), it is closer to N 10°-20°E. It is not clear whether these are accidental fluctuations or indeed systematic features.

Regarding the "anomalous areas", one might argue that a completely different joint-system may be predominant in these. These are joints striking NE and NW. Vestiges of such joint systems are also visible in the "third" maxima of some of the non-anomalous locations. Even if such maxima did not specifically show up in the statistical evaluation of a location, the corresponding joint sets may, on occasion, be visible *in natura* at an outcrop. Thus, Fig. 2, shows a photograph of an outcrop in shale near Moyie Lake. The orientations for the shown joints are, clockwise: 182/80, 262/80, 107/82. The two rectangular joints are indeed those that correspond to the NE-directed P-direction, the additional joint may belong to the same system as the predominant ones in the "anomalous" locations.

Fig. 2 - Photograph of the "regular" joints (shown at right angles) and an "anomalous" joint (oblique in center) at an outcrop near Moyie Lake, B.C.

4. Discussion

The general NE-SW orientation of the maximum pressure direction would appear to agree with the usual concepts of the direction of the neotectonic intraplate stresses. These are usually assumed as "normal" to the Rocky Mountain front (Bell and Gough, 1979). However, it is not entirely easy to define the *strike* of the Rocky Mountain front, inasmuch as the latter swerves substantially. At any rate, in the North, our values are somewhat closer to NNE, in the South, to NE. A more detailed analysis of Gough and Bell (1980) of oil well breakout data also shows many instances of NNE rather than NE maximum pressure directions. Joint orientations agreeing with ours appear also to have been found by Babcock (1974) in those of his study areas which are closest to the Rocky Mountains (see p. 94, loc. cit.).

The fact that 4 of the 23 locations show entirely anomalous joints orientations, is by no means unusual. World-wide, it is observed that about 20% of locations in a region show such anomalous behavior. Inasmuch as there is still some uncertainly regarding the very nature of the points (see Scheidegger, 1979), it cannot be stated for sure whether an older joint-system or indeed a local variation of the stress field is involved in this connection.

Acknowledgments

The research reported here was made possible through the kind invitation of Dr. D.I. Gough, Head of the Earth and Planetary Physics Institute at the University of Alberta in Edmonton to the writer to spend a month in Canada. The opportunity thus afforded to the writer for doing the research reported here is gratefully acknowledged.

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