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WESTERN CANADA SEDIMENTARY BASIN
BOREHOLE IMAGERY ANALYSIS PROJECT:
A SUMMARY OF MOBIL
PINCHER CREEK 16-13-3-29W4

R.E. McCallum and J.S. Bell



Canada

INSTITUTE OF SEDIMENTARY
AND PETROLEUM GEOLOGY



**GEOLOGICAL SURVEY OF CANADA
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R.E. McCallum¹ and J.S. Bell²

¹ R.E.M. Consulting, 1447 - 19 Ave. S.W., Calgary, Alberta T2T 0J1

² Geological Survey of Canada, Calgary
3303 33 Street N.W., Calgary, Alberta T2L 2A7

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**Western Canada Sedimentary Basin Borehole Imagery Analysis
Project: A Summary of MOBIL Pincher Creek 16-13-3-29W4**

Well Name: MOBIL Pincher Creek 16-13-3-29W4

Operator: Mobil Oil

Location: latitude 49° 12' 58.3"
longitude 113° 46' 12.6"
(see figure 1)

Rig Release Date: November 26, 1989

Imagery Log/Interval Logged: FMS 4044.9 m - 4278.5 m

Well Trajectory: Semi-vertical, deviated

Drill Bit Size: 8.5 inches over the interval logged

Formations Logged and Tops:	Mississippian Banff	3868.0 m
	Devonian Exshaw	4052.0 m
	Devonian Wabamun	4055.8 m
	Devonian Nisku	4243.0 m
	Devonian Ireton	4256.0 m

Lithologies: The section logged consists of Lower Mississippian Banff Formation carbonates, Upper Devonian shales of the Exshaw Formation, Upper Devonian carbonates of the Wabamun and Nisku Formations, and shales of the Ireton Formation.

Core Intervals: No cores cut.

Structural Setting: Southern flank of the Western Canada Sedimentary Basin.

Regional Stress trajectories: The nearest well with stress orientation data is Chevron et al Carway 3-2-2-26W4 located 31.4 kms SE with a S_{Hmin} direction of 141.0° N (Bell et al, 1994).

Description of Images:

Discontinuous Semi-Vertical Fractures: Two semi-vertical discontinuous fractures were observed in the interval logged and examples are given in figures 2 and 3. The fractures are characterized by thin, discontinuous, dark (conductive) traces appearing 180° apart on the FMS microresistivity images. The interpretive software program BORVIEW converts digital microresistivity contrasts into brown-yellow tones (dark colors indicate high conductivity whereas light colors indicate low conductivity, Bourke et al 1989) and applies a sinusoidal curve to arrive

at a true dip angle and dip azimuth.

Chatter Fractures: Short, discontinuous, dark (conductive) traces on the FMS log that trend obliquely to borehole trajectory and occur in groups in an en echelon, steplike fashion are interpreted as drilling induced chatter fractures. These appear on opposite sides of the borehole wall 180° to each other. Figures 4, 5, 6, and 7 are examples of the 14 chatter fractures measured in MOBIL Pincher Creek 16-13-3-29W4.

Bedding Planes: Seventy-six measurements of bedding planes were made at regular intervals to supplement the data set. Figures 8 and 9 illustrate examples.

Results:

Discontinuous Semi-Vertical Fractures: In MOBIL Pincher Creek 16-13-3-29W4 two semi-vertical fractures are found throughout the interval logged by the FMS tool. On FMS microresistivity images they are characterized by thin, discontinuous, dark (conductive), linear traces that approximately parallel borehole trajectory, cross-cut bedding, and are open and mud-filled. The fractures have lengths of approximately 1.0 m and 1.5 m. Strike azimuths are summarized in the rosette diagram in figure 12a and dip angles and dip azimuths are presented by a feature attribute summary (figure 10) and a Wulf stereonet (figure 11). The mean strike from the 2 samples is 049.4° N +/- 6.1°.

It is believed that these fractures form as hydraulic fractures in response to pressure exerted on the undrilled rock by the weight of the drillstem during drilling. Alternatively, fracture generation may be the result of the drillpipe acting as a loose fitting piston when it is run into the hole too quickly. This action will cause bottomhole pressures to exceed the parting pressure of the rocks (Dickey, 1986).

Hydraulic fractures propagate within the plane formed by the largest and intermediate principal stresses (S_v and S_{Hmax}) and are extensional. S_v is vertical and thus induced fractures can be used to detect the direction of the maximum horizontal principal stress (S_{Hmax}). As figure 12a illustrates, this would suggest an S_{Hmax} azimuth of 049.4° N.

Chatter Fractures: Figures 10 and 11 summarize the orientations of the 14 chatter fractures observed in MOBIL Pincher Creek 16-13-3-29W4 and strike orientations are depicted by a rosette in figure 12b. Figure 11 reveals two distinct populations of chatter fractures each with similar dip magnitudes but dip directions 180° opposite each other (see also figure 2). Bedding orientations near both populations are constant. Mean strike azimuth for the entire fracture set is computed as 054.0° N (+/- 6.9°). Chatter fractures often appear on opposite sides of the borehole wall and may be stratabound. They are believed to be "drilling enhanced" natural fractures (Heliot et al, 1990) formed when a preexisting natural fracture is opened preferentially in the plane of S_{Hmax} and S_v in response to pressure exerted on the rock formation during drilling. This gives rise to the characteristic en echelon, steplike fashion of chatter fractures where the fracture traces are seen at the borehole azimuths of the maximum horizontal stress direction. As figure 12b illustrates, this would give an S_{Hmax} azimuth of 054.0° N. The larger number of chatter fracture measurements make them a more reliable indicator of S_{Hmax} direction than the fewer semi-vertical fractures.

Bedding Planes: Seventy-six bedding plane orientations were measured and their orientations are summarized in figures 10, 11, and 13. In the initial investigation of this well it was thought that the high angle bedding planes seen at 4210 m and deeper were actually natural fractures due to their resemblance of naturally occurring fractures found elsewhere in these studies (McCallum and Bell, 1995). Closer examination of the features, however led us to interpret them as high angle bedding planes in highly folded strata.

Discussion

Figure 10 summarises the distribution of induced and natural fractures logged between 4044.9 m and 4278.5 m KB in Mobil Pincher Creek 16-13-3-29W4.

The induced fractures fall into two populations: 1) a northwest-dipping set of mostly chatter fractures that become more steeply inclined between 4056.2 m and 4120.8 m, and 2) a southeasterly dipping set of chatter fractures between 4184 m and 4187 m (see Table of Chatter Fracture data). It is clear that the two semi-vertical drilling-induced fractures at 4102.8 m and 4114.2 m are gradational with the chatter fractures that occur around them.

The different dips of the two chatter fracture populations are of interest. Aadnoy's (1990) analysis suggests that chatter fractures form because one principal stress axis (in this case, the "near vertical principal stress") is not aligned parallel with the well bore. This situation can arise when stress axes are influenced by surface topography, or when they are controlled by local structure, such as overthrusting. In Mobil Pincher Creek 16-13-3-29W4, it is clear that the wellbore is not aligned with one stress axis near the top of the logged section, that the alignment becomes almost parallel at approximately 4100 m, and that the well trajectory again becomes misaligned with the stress axis by 4184 m. Is this a case of structural control at all levels, or is the upper non-aligned population responding to topography? More data are needed, particularly between the ground surface and the logged interval, in order to resolve the matter.

When the vertical deviation of a well is taken into account, it can modify the interpretation of the stress axes, so that the larger horizontal stress will not, for example, exactly coincide with the mean strike of chatter fractures. Appropriate corrections have not been made here, which should be born in mind when assessing the interpretation. The difference in S_{Hmax} azimuth is not likely to be huge, but it could amount to several degrees.

Conclusions

In MOBIL Pincher Creek 16-13-3-29W4 interpretations of the FMS microresistivity images indicate a mean S_{Hmax} direction of 054.0° N. This orientation is in agreement with regional trends of S_{Hmax} as summarized in figure 1. No S_{Hmin} directions were obtained due to the lack of suitable features appearing on the microresistivity logs to enable us to determine S_{Hmin} . However, the nearest well with stress orientation data is Chevron et al Carway 3-2-2-26W4 located 31.4 kms SE with a S_{Hmin} direction of 141.0° N (Bell et al, 1994) which approximates stress orientations found in Figure 1.

Figure 1. Location of Pincher Creek 16-13-3-29W4 with respect to the stress regime of the Western Canada Sedimentary Basin.

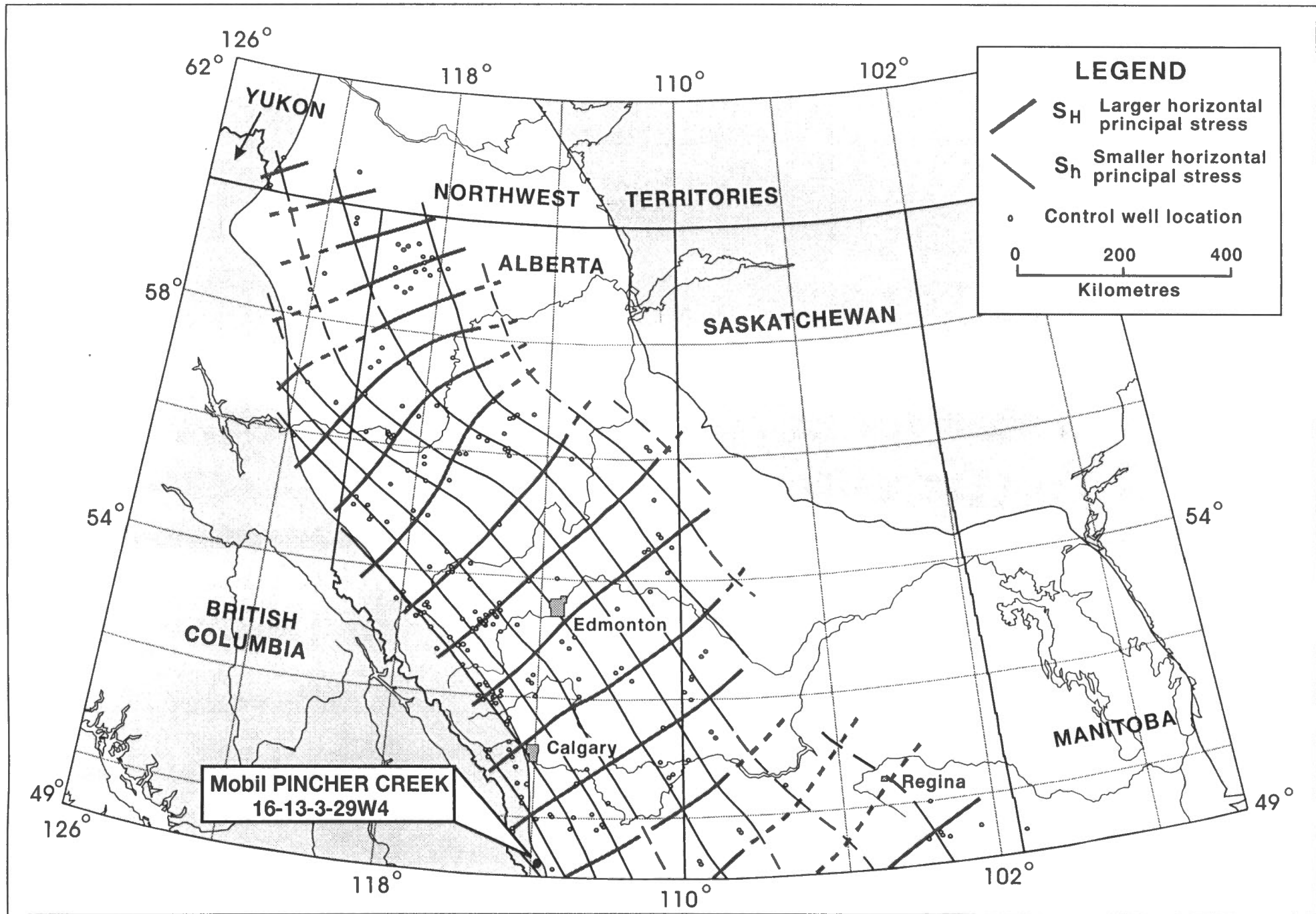


Fig. 1. Location of Mobil PINCHER CREEK 16-13-3-29W4

Figure 2. A semi-vertical discontinuous fracture at the 4102.0 to 4103.5 m mark within carbonates of the Upper Devonian Wabamum Formation. The fracture is characterized by discontinuous linear, dark (conductive) traces appearing at opposite sides of the borehole at azimuths of 060° and 240°. It dips at 89° with a dip azimuth of 325° (strike direction 055° N). Vertical scale is 1:10, horizontal scale is 1:5.

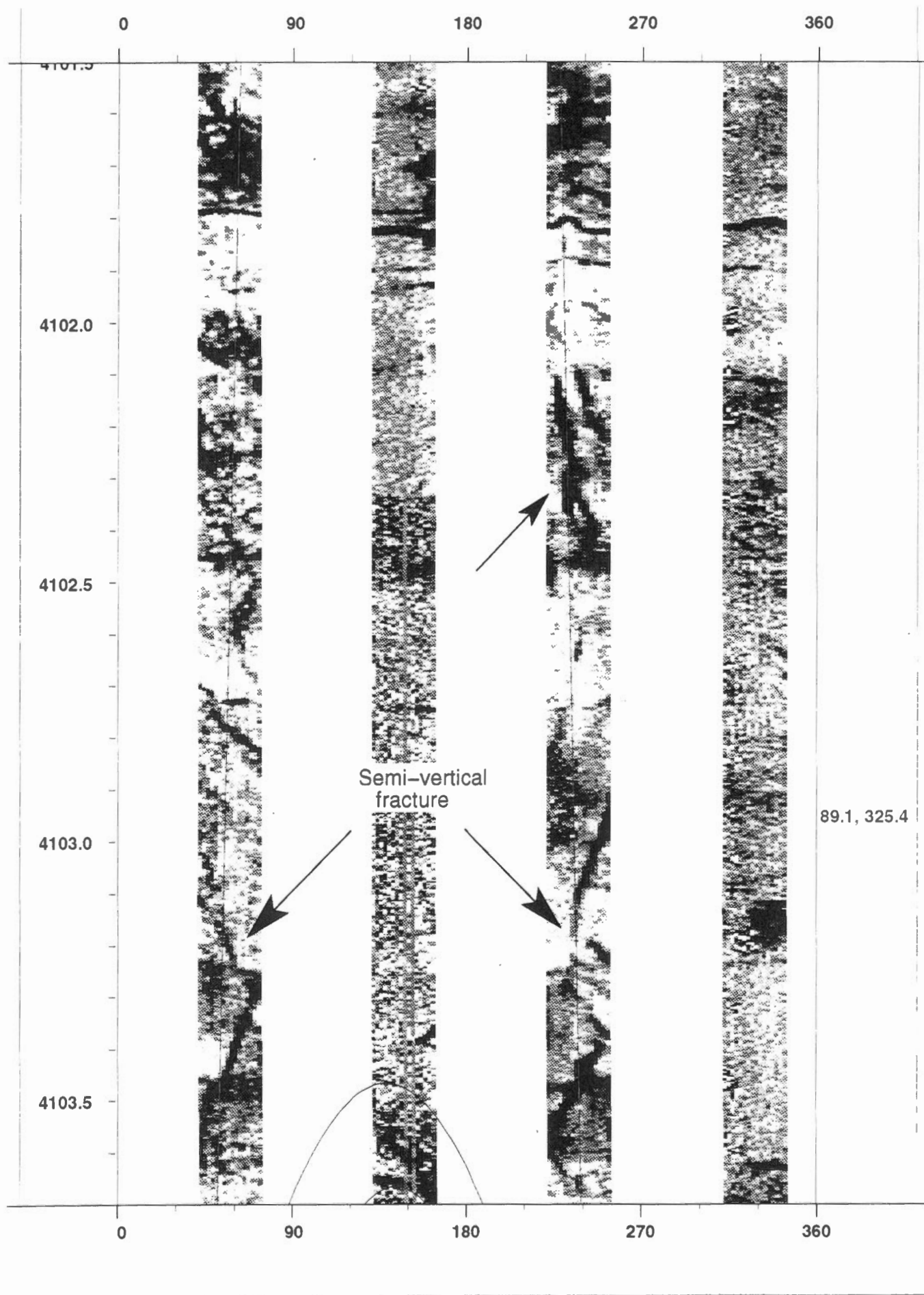


Figure 3. A discontinuous semi-vertical fracture at the 4114.0 m mark within the Upper Devonian Wabamum Formation. The fracture dips at 87° with a dip azimuth of 313° (strike 043° N). Vertical scale is 1:10, horizontal scale is 1:5.

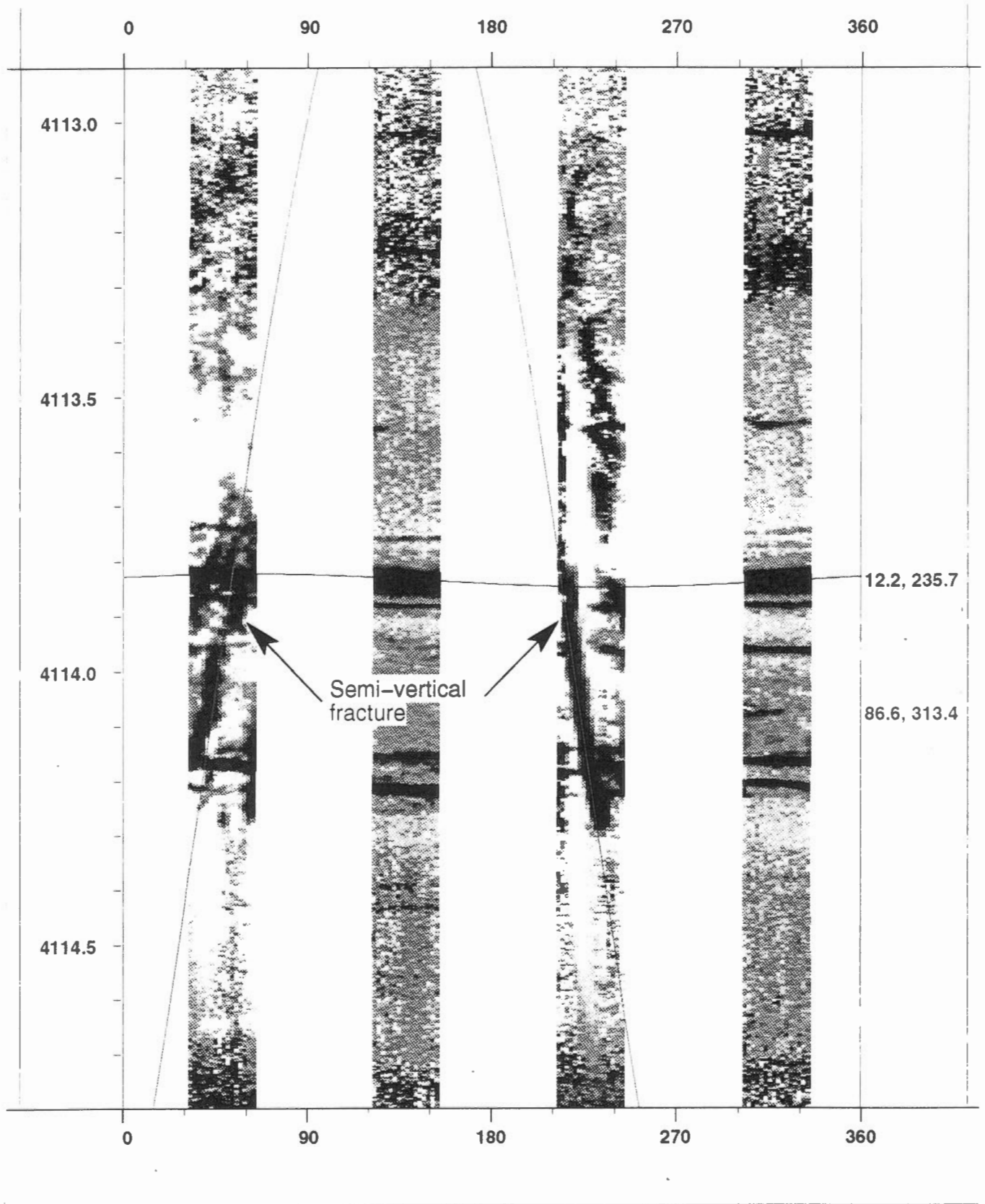


Figure 4. A chatter fracture with plotted orientations within carbonates of the Lower Mississippian Banff Formation. The fracture dips at 73° and strikes 039° and appears on opposite sides of the borehole 180° apart. Vertical scale is 1:10, horizontal scale is 1:5.

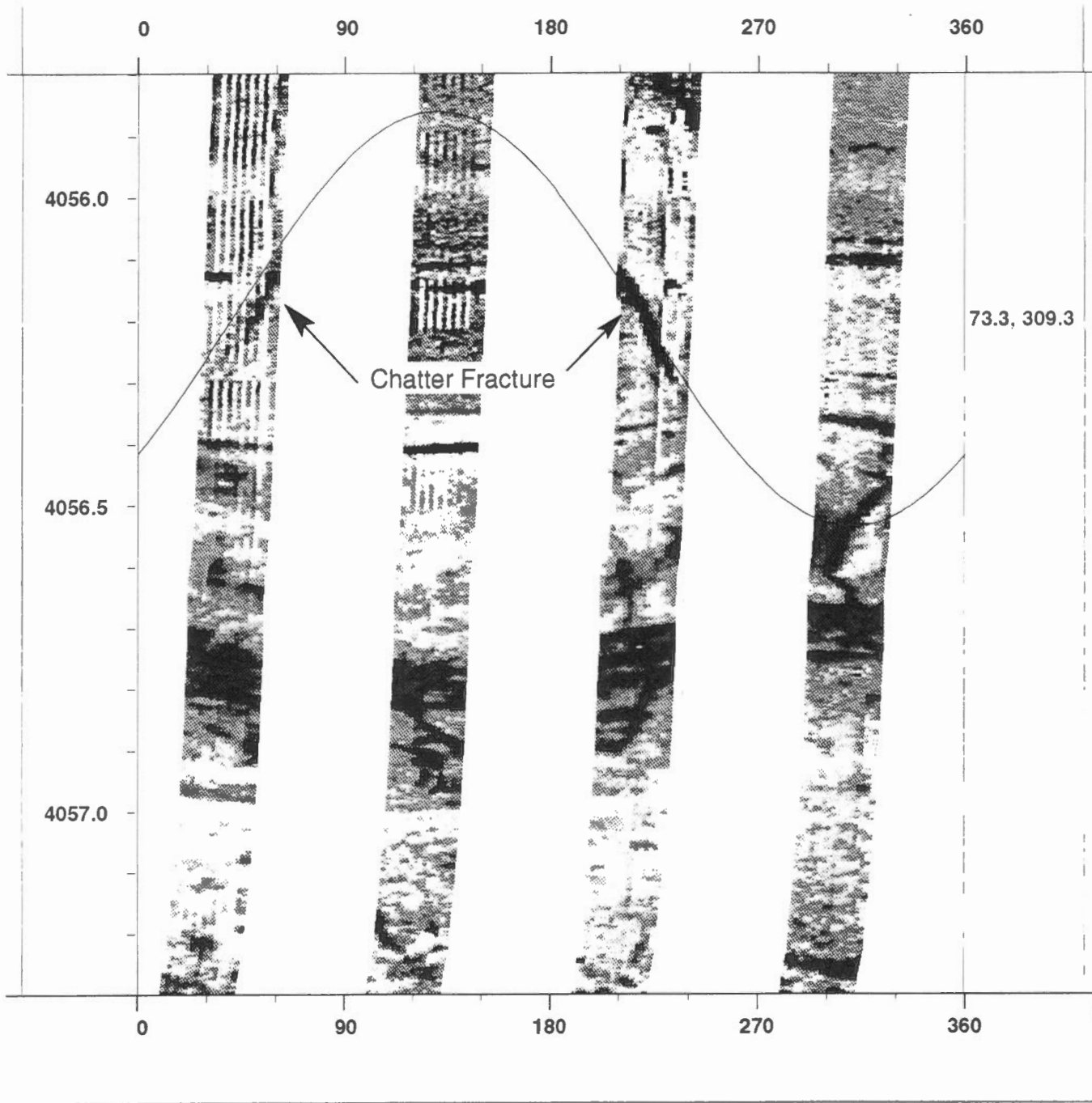


Figure 5. Chatter fractures and their plotted orientations within carbonates of the Upper Devonian Wabamum Formation. The fractures overlap each other in a slanted, en echelon, step-like fashion. They appear on opposite sides of the borehole 180° apart. Vertical scale is 1:10, horizontal scale is 1:5.

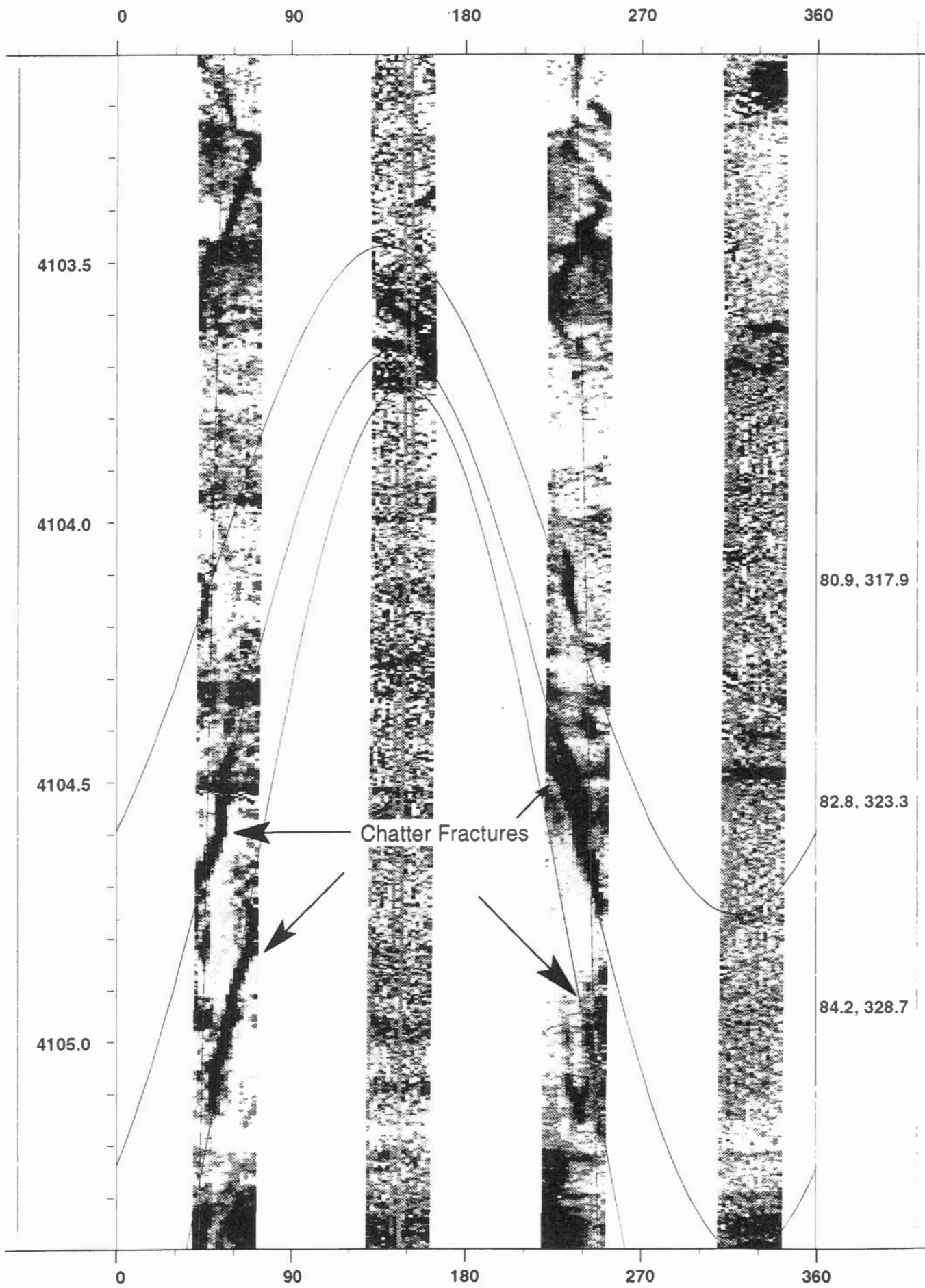


Figure 6. Chatter fractures and their plotted orientations within carbonates of the Upper Devonian Wabamum Formation. The fractures overlap each other in a slanted, en echelon, step-like fashion. They appear on opposite sides of the borehole 180° apart. Vertical scale is 1:10, horizontal scale is 1:5.

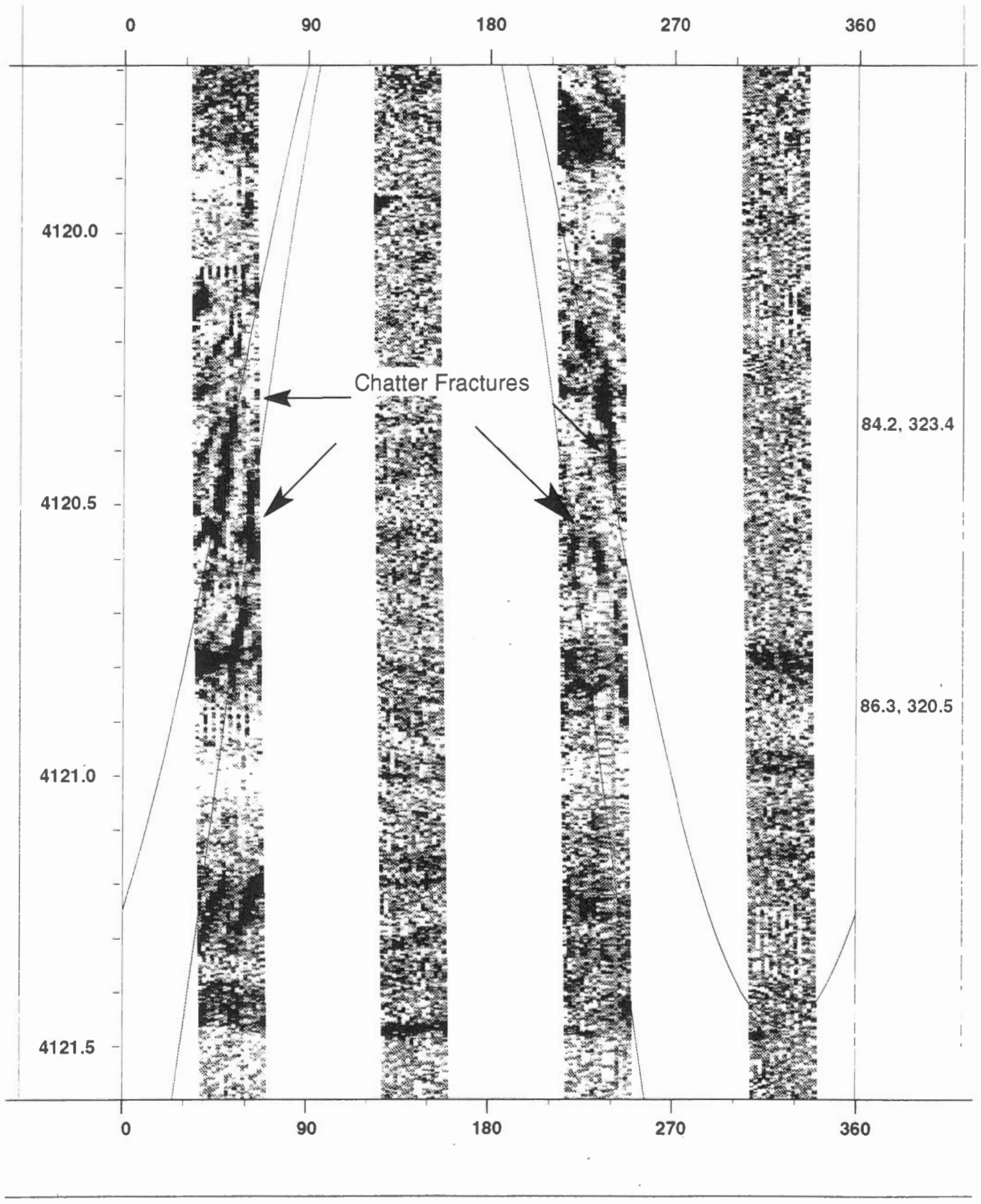


Figure 7. Chatter fractures and their plotted orientations within carbonates of the Upper Devonian Wabamum Formation. This group of chatter fractures represents a second population of such fractures that exhibit a dip magnitude similar to the chatter fractures encountered up hole (see figures 4-6) except the dip azimuth is 180° opposite towards the southeast (see figure 11). Bedding orientations near both populations are constant (see figure 2). Vertical scale is 1:10, horizontal scale is 1:5.

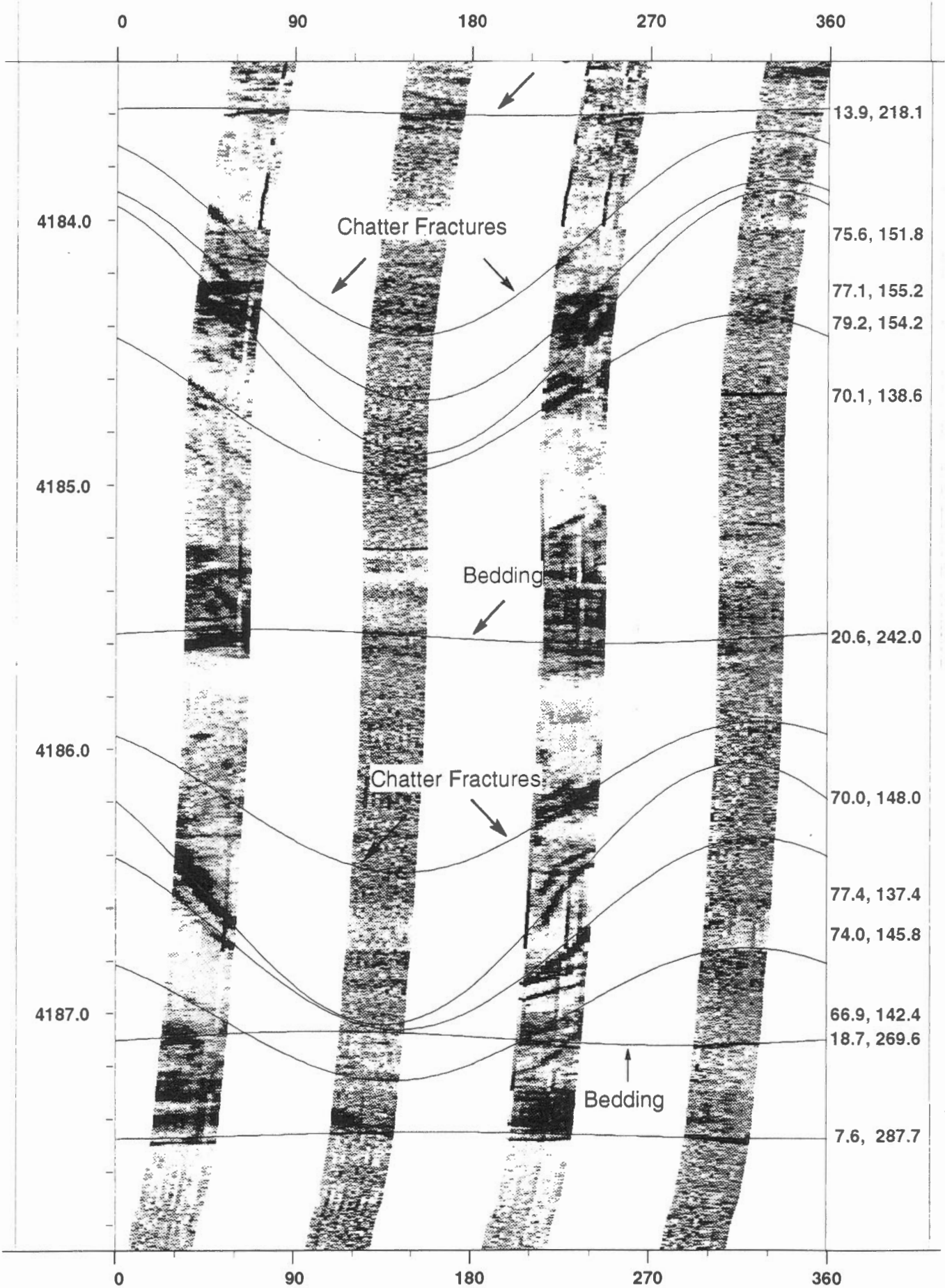


Figure 8. Examples of high angle bedding planes in the Upper Devonian Wabamun carbonates. During initial study of this well, these features were thought to be naturally occurring fractures given their resemblance to similar features seen in other borehole imagery investigations. Vertical scale is 1:20, horizontal scale is 1:5.

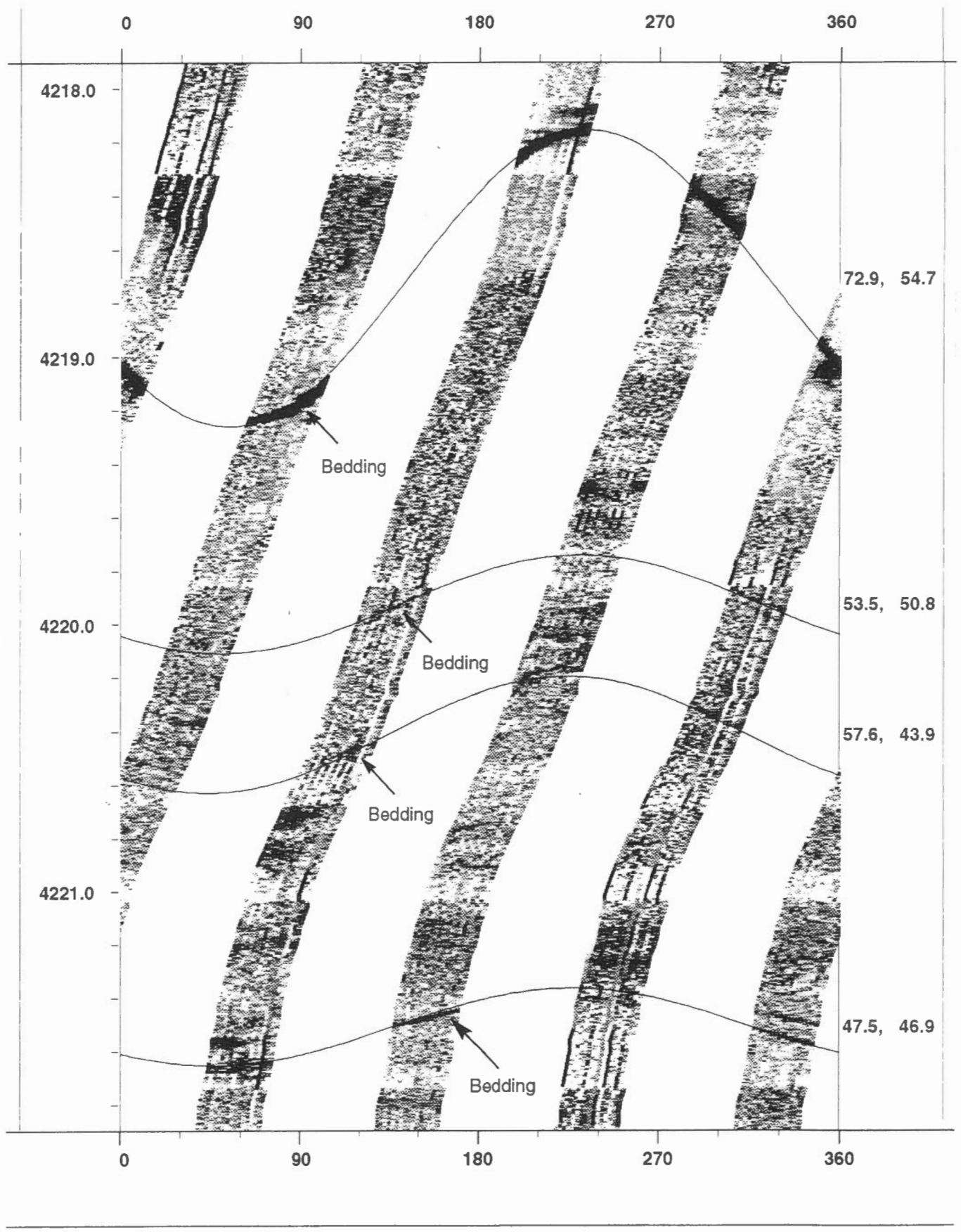


Figure 9. Examples of highly folded strata within the Devonian Ireton Formation.
Vertical scale is 1:20, horizontal scale is 1:5.

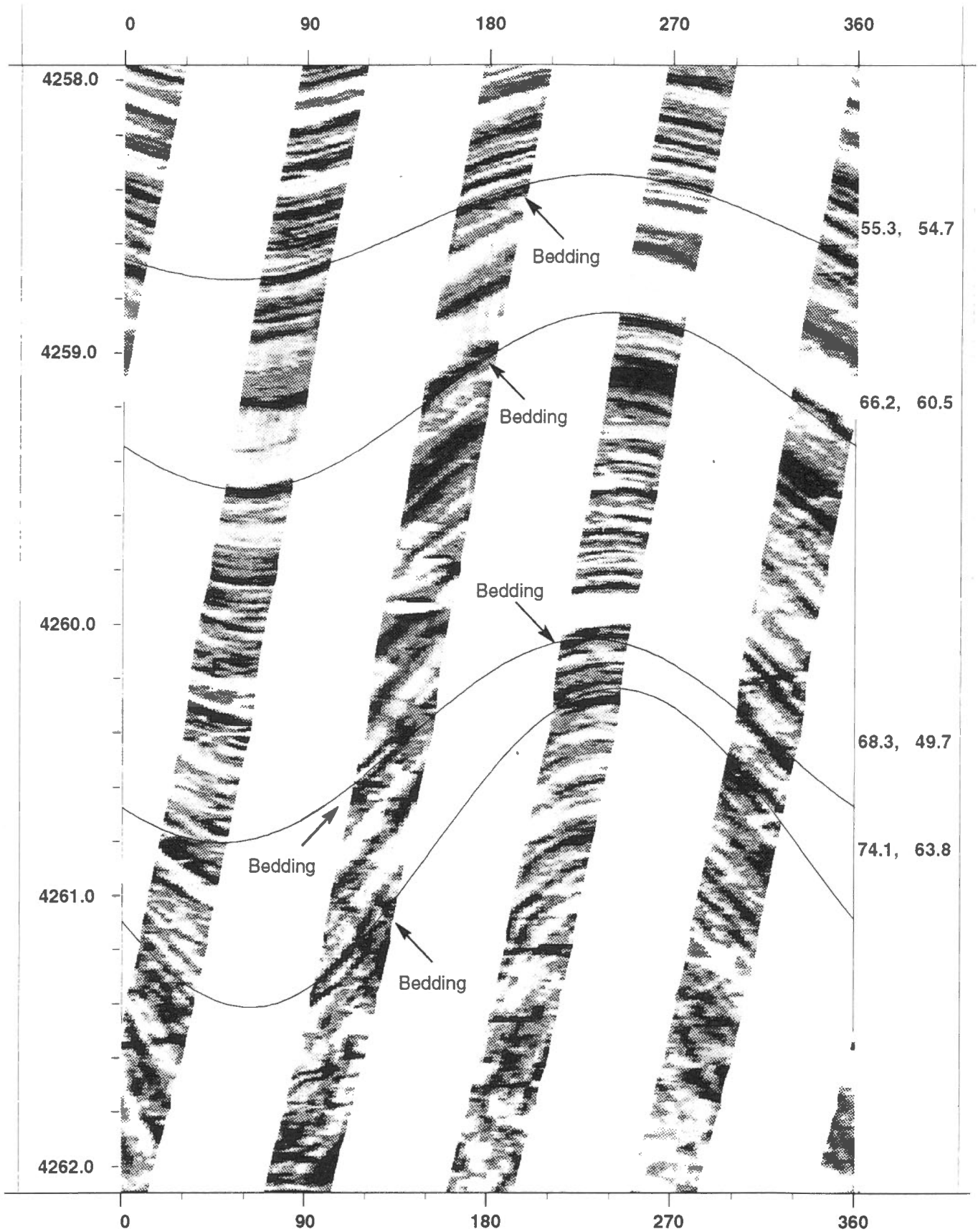


Figure 10. A well overview diagram of the entire Pincher Creek 16-13-3-29W4 well summarizing strike and dips of the various features measured.

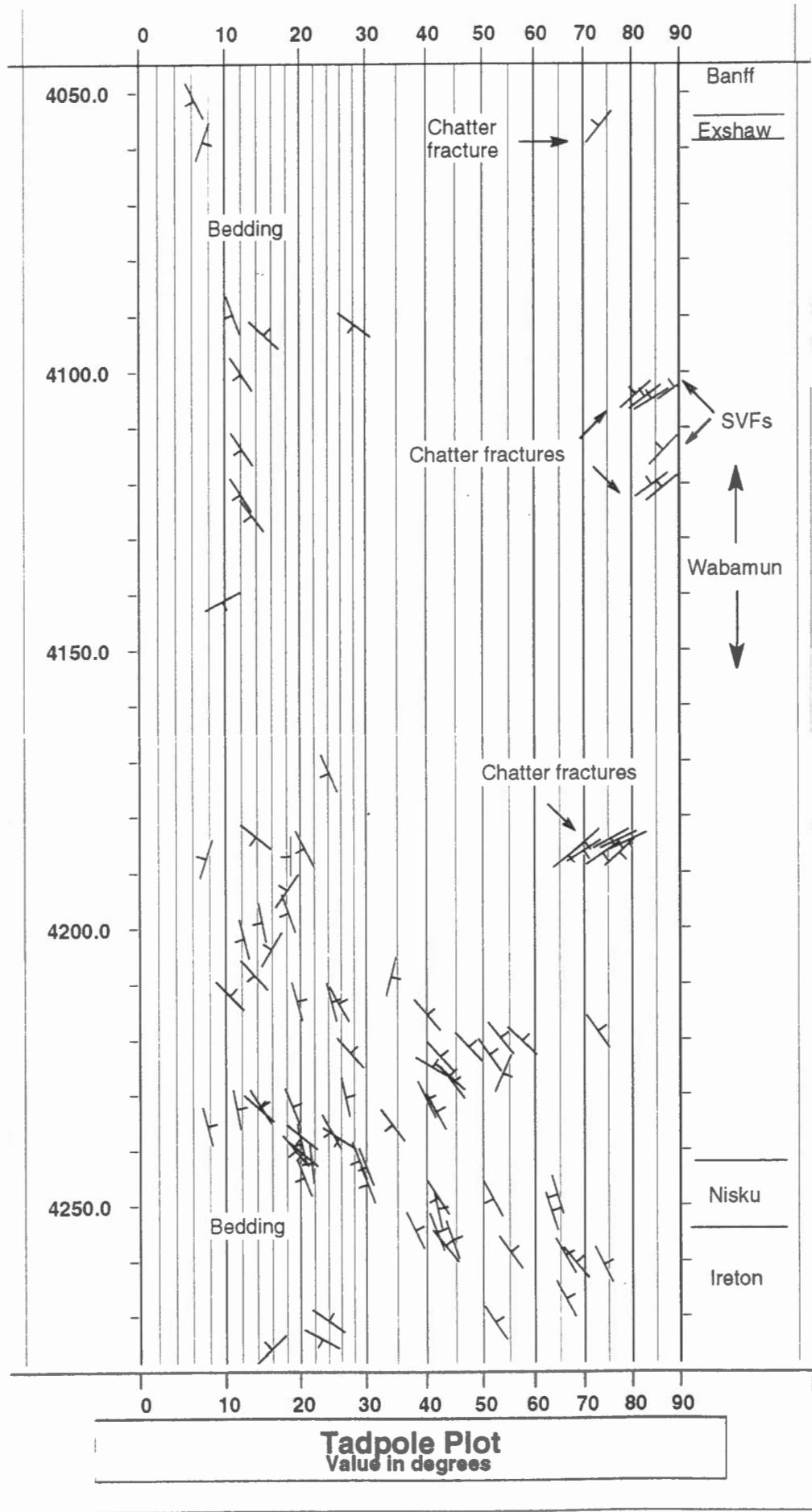


Figure 11. Wulf stereonet summary diagram of all features types in Pincher Creek 16-13-3-29W4. The diagram shows dip angles and dip azimuths of the features.

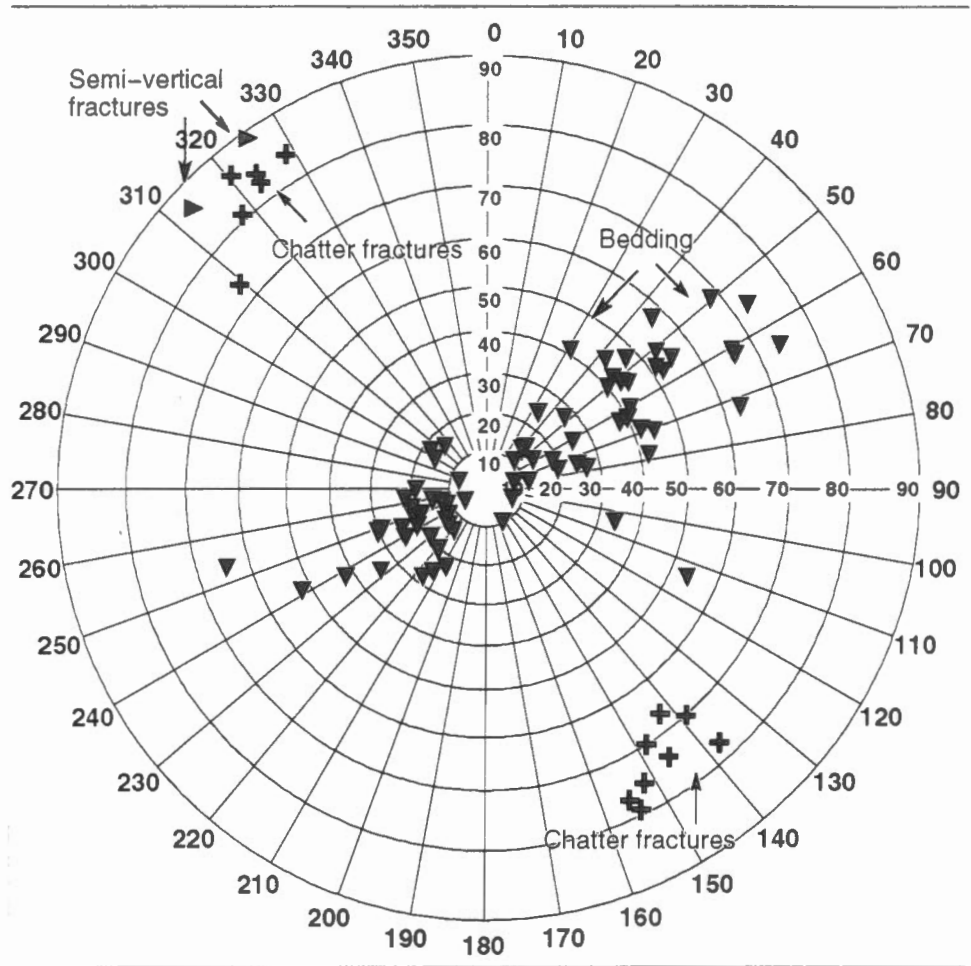


Figure 12a. Strike azimuth rosette diagram of semi-vertical fractures in Pincher Creek 16-13-3-29W4. Mean strike from 2 samples is computed as $049.4^{\circ} \pm 6.1^{\circ}$.

Figure 12b. Strike azimuth rosette of chatter fractures in Pincher Creek 16-13-3-29W4. Mean strike for 14 samples is computed as $054.0^{\circ} \pm 6.9^{\circ}$.

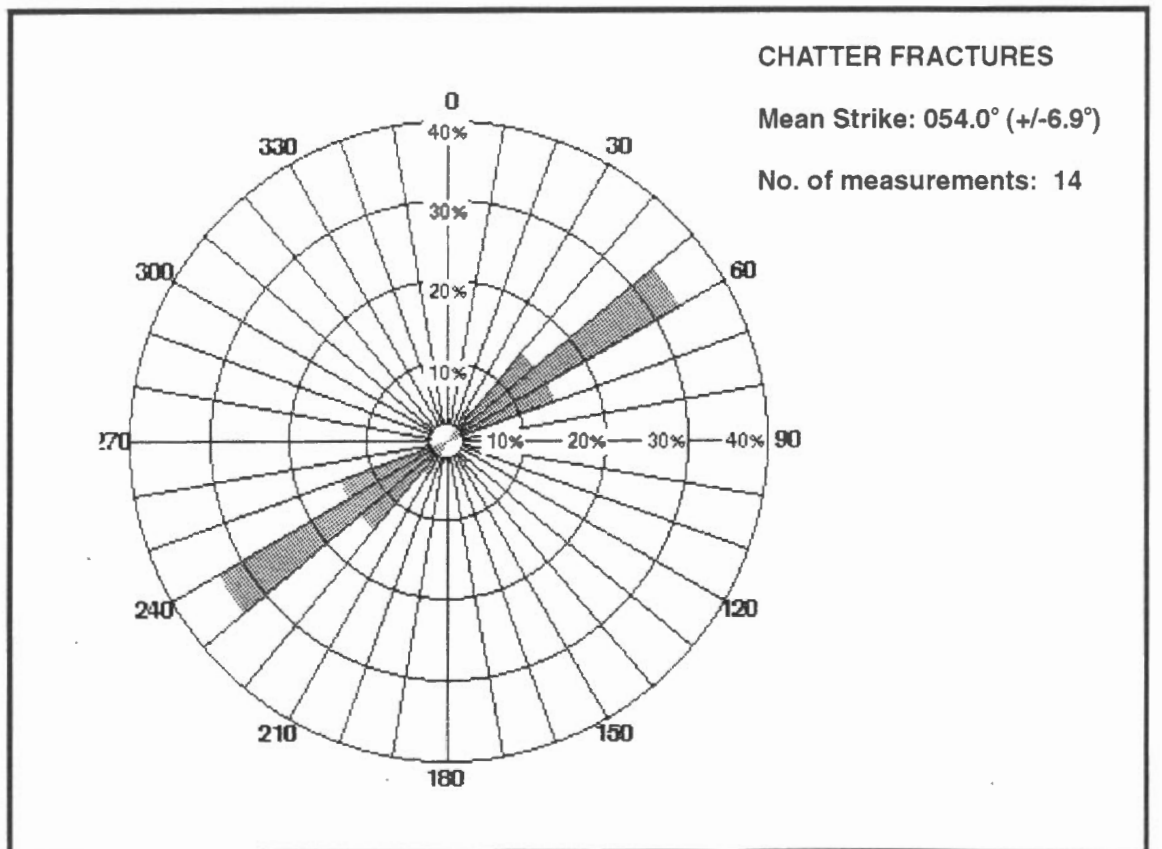
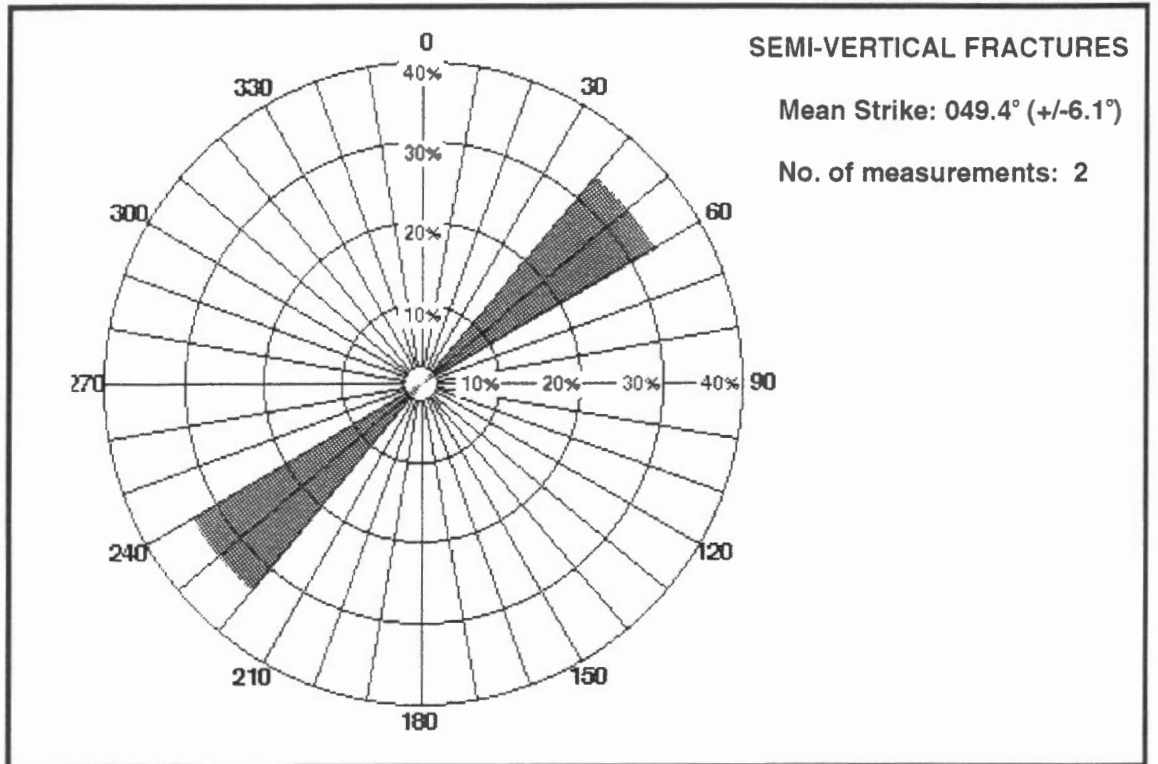
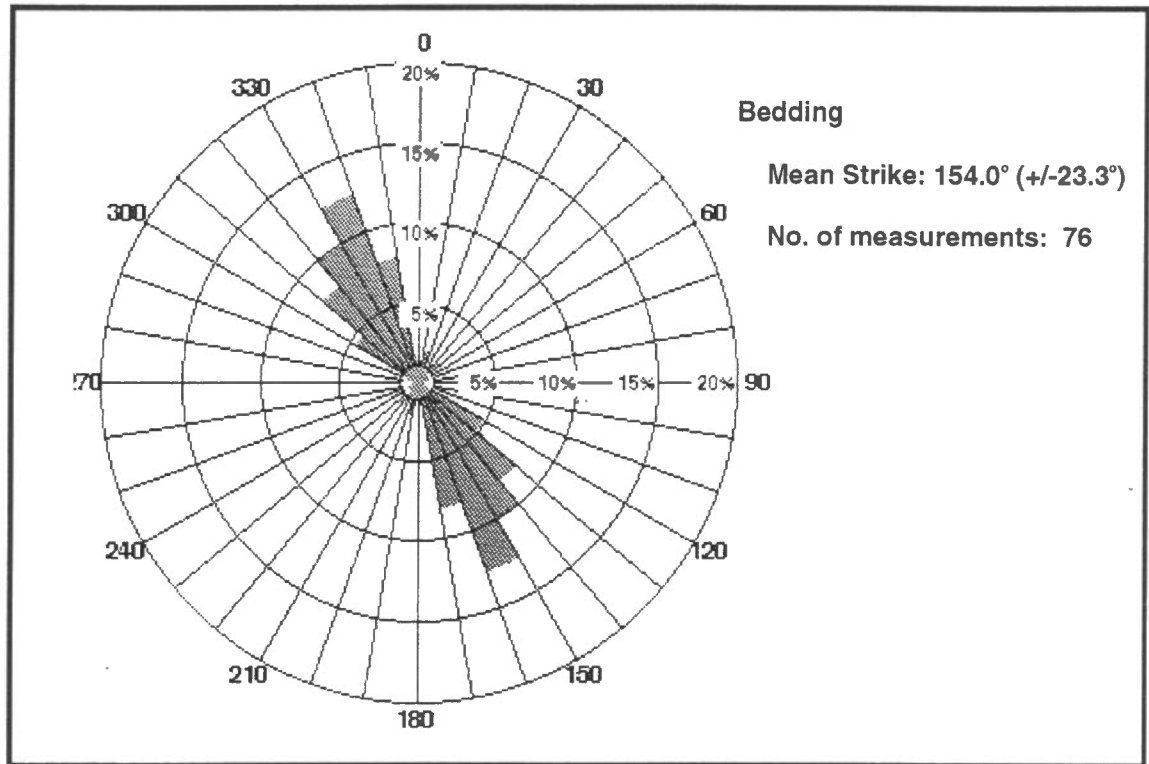


Figure 13. Strike azimuth rosette of bedding planes measured in Pincher Creek 16-13-3-29W4. Mean strike for the 76 measured samples is computed as $154.0^{\circ} \pm 23.3^{\circ}$.



References

- Aadnoy, B. S., 1990. In-situ stress directions from borehole fracture traces. *Journal of Petroleum Science and Engineering*, v. 4, p. 143-153.
- Bell, J.S. and Babcock, E.A.
1986: The stress regime of the western Canadian Basin and implications for hydrocarbon production; *in* *Bulletin of Canadian Petroleum Geology*, v.34, p. 364-378.
- Bell, J.S., Price, P. R., and McLellan P. J.
1994: In-situ stress in the western Canada sedimentary basin; *in* *Geological Atlas of the Western Canada Sedimentary Basin*, Mossop, G. D. and Shetsen, I., (Editors), Canadian Society of Petroleum Geologists and Alberta Research Council, p. 439-446.
- Bourke, L., Delfiner, P., and Fett, T.
1989: Using Formation Microscanner images; *in* *The Technical Review*, v.37, no.1, p.16-40.
- Dickey, P. A.
1986: *Petroleum Development Geology*, 3rd ed.
- Ekstrom, M.P., Dahan, C.A., Chen, M.Y., Lloyd, P.M., and Rossi, D.J.
1987: Formation imaging with microelectrical arrays; *in* *The Log Analyst*, May-June, p.294-306.
- Heliot, D., Etchecopar, A., and Cheung, Ph.
1990: New developments in fracture characterization from logs; *in* Maury and Fourmaintraux (Eds), *Rock at Great Depth*, p.1471-1478.
- Lehne, K.A. and Aadnoy, B.S.
1992: Quantitative analysis of stress regimes and fractures from logs and drilling records of a north sea chalk field; *in* *The Log Analyst*, July-August, p. 351-359.
- Mardia, K.V.
1972: *Statistics of directional data: probability and mathematical statistics*; Academic Press, London and New York, 357 p.
- McCallum R. E. and Bell, J. S.
1995: Diagnosing natural and drilling-induced fractures from borehole images of western Canadian wells; *in* *Proceedings of the Oil and Gas forum '95 - Energy from Sediments*, Bell, J.S., Bird, T.D., Hillier, T. and Greener, P.L., Editors, Geological Survey of Canada Open File Report No. 3058, p. 79-82.
- Parker, D.L., and Hefferman, P.D.
1992: Methods of determining induced fracture orientation - Ferrier field application; *in* *Journal of Canadian Well Logging Society*, vol. 18, p.7-20.

Plumb, P.A., and Hickman, S. H.

1985: Stress-induced borehole elongation: a comparison between the Four-Armed Dipmeter and the Borehole Televiewer in the Auburn geothermal well; in Journal of Geophysical Research, vol.90, No.B7, p.5513-5521, June.

Plumb, R.A.

1989: Fracture patterns associated with incipient wellbore breakouts; in Maury and Fourmaintraux (Eds), Rock at Great Depth, p.761-768.

Prensky, S.

1992: Borehole breakouts and in-situ stress - a review; in The Log Analyst, May-June, p.304-312.

Well Name: Mobil Pincher Ck 16-13-3-29W4							
Semi-Vertical Fractures							
Depth KB m	Strike Azi of feature	Sin Azi	Cumulative Total Sin Azi	Cos Azi	Cos Azi corrected for zero values	Cumulative Total Cos Azi	Measurement made or not 1 or 0 entered
4051.3	0.0	0.000	0.000	1.000	0.000	0.000	0
4056.2	0.0	0.000	0.000	1.000	0.000	0.000	0
4058.7	0.0	0.000	0.000	1.000	0.000	0.000	0
4089.7	0.0	0.000	0.000	1.000	0.000	0.000	0
4091.5	0.0	0.000	0.000	1.000	0.000	0.000	0
4093.4	0.0	0.000	0.000	1.000	0.000	0.000	0
4100.3	0.0	0.000	0.000	1.000	0.000	0.000	0
4102.8	235.4	-0.823	-0.823	-0.568	-0.568	-0.568	1
4104.0	0.0	0.000	-0.823	1.000	0.000	-0.568	0
4104.6	0.0	0.000	-0.823	1.000	0.000	-0.568	0
4104.9	0.0	0.000	-0.823	1.000	0.000	-0.568	0
4113.8	0.0	0.000	-0.823	1.000	0.000	-0.568	0
4114.2	223.4	-0.687	-1.510	-0.727	-0.727	-1.294	1
4120.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4120.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4121.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4125.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4141.1	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4172.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4183.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4184.0	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4184.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4184.4	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4184.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4185.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4186.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4186.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4186.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4187.0	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4187.1	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4187.5	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4193.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4197.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4198.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4201.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4203.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4208.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4208.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4212.1	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4213.1	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4213.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4213.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4215.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4218.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4220.0	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4220.5	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4221.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4222.5	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4223.0	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4223.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4225.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4226.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4226.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0

4227.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4230.5	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4231.0	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4232.1	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4232.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4232.4	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4232.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4233.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4235.5	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4235.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4236.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4237.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4237.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4238.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4240.1	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4240.5	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4241.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4242.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4243.1	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4245.0	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4246.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4248.2	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4248.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4248.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4250.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4251.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4254.7	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4254.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4256.3	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4257.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4258.6	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4259.4	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4260.5	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4260.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4266.9	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4270.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4271.4	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4274.0	0.0	0.000	-1.510	1.000	0.000	-1.294	0
4275.8	0.0	0.000	-1.510	1.000	0.000	-1.294	0

arithmetic mean of strike values (col 2) =

229.4

Total measurements taken =

2

Feature Orientation measurements **Well: Mobil Pincher Creek 16-13-3-29W4 Semi-Vertical Fractures**

Reference Mardia 1972 for statistics of directional data

Total Sin x thick	Total Cos x thick	Total Thickness	S Col A/ColC	C ColB/ColC	R x R	R	S/R	C/R	Azimuth from S/R	Azimuth from C/R	Standard Deviation
-1.51	-1.294	2	-0.7550	-0.6470	0.9886	0.9943	-0.7593	-0.6507	229.4	229.4	6.1

Well Name: Mobil Pincher Ck 16-13-3-29W4							
Chatter Fractures							
Depth KB m	Strike Azi of feature	Sin Azi	Cumulative Total Sin Azi	Cos Azi	Cos Azi corrected for zero values	Cumulative Total Cos Azi	Measurement made or not 1 or 0 entered
4051.3	0.0	0.000	0.000	1.000	0.000	0.000	0
4056.2	219.3	-0.633	-0.633	-0.774	-0.774	-0.774	1
4058.7	0.0	0.000	-0.633	1.000	0.000	-0.774	0
4089.7	0.0	0.000	-0.633	1.000	0.000	-0.774	0
4091.5	0.0	0.000	-0.633	1.000	0.000	-0.774	0
4093.4	0.0	0.000	-0.633	1.000	0.000	-0.774	0
4100.3	0.0	0.000	-0.633	1.000	0.000	-0.774	0
4102.8	0.0	0.000	-0.633	1.000	0.000	-0.774	0
4104.0	227.9	-0.742	-1.375	-0.670	-0.670	-1.444	1
4104.6	233.3	-0.802	-2.177	-0.598	-0.598	-2.042	1
4104.9	238.7	-0.854	-3.032	-0.520	-0.520	-2.561	1
4113.8	0.0	0.000	-3.032	1.000	0.000	-2.561	0
4114.2	0.0	0.000	-3.032	1.000	0.000	-2.561	0
4120.3	233.4	-0.803	-3.834	-0.596	-0.596	-3.158	1
4120.8	230.5	-0.772	-4.606	-0.636	-0.636	-3.794	1
4121.9	0.0	0.000	-4.606	1.000	0.000	-3.794	0
4125.7	0.0	0.000	-4.606	1.000	0.000	-3.794	0
4141.1	0.0	0.000	-4.606	1.000	0.000	-3.794	0
4172.2	0.0	0.000	-4.606	1.000	0.000	-3.794	0
4183.6	0.0	0.000	-4.606	1.000	0.000	-3.794	0
4184.0	241.8	-0.881	-5.487	-0.473	-0.473	-4.266	1
4184.3	245.2	-0.908	-6.395	-0.419	-0.419	-4.686	1
4184.4	244.2	-0.900	-7.295	-0.435	-0.435	-5.121	1
4184.7	228.6	-0.750	-8.046	-0.661	-0.661	-5.782	1
4185.6	0.0	0.000	-8.046	1.000	0.000	-5.782	0
4186.2	238.0	-0.848	-8.894	-0.530	-0.530	-6.312	1
4186.6	227.5	-0.737	-9.631	-0.676	-0.676	-6.988	1
4186.7	235.8	-0.827	-10.458	-0.562	-0.562	-7.550	1
4187.0	232.4	-0.792	-11.250	-0.610	-0.610	-8.160	1
4187.1	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4187.5	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4193.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4197.2	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4198.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4201.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4203.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4208.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4208.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4212.1	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4213.1	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4213.2	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4213.7	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4215.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4218.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4220.0	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4220.5	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4221.6	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4222.5	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4223.0	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4223.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4225.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4226.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4226.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0

4227.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4230.5	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4231.0	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4232.1	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4232.2	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4232.4	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4232.6	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4233.2	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4235.5	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4235.7	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4236.7	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4237.6	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4237.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4238.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4240.1	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4240.5	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4241.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4242.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4243.1	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4245.0	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4246.2	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4248.2	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4248.6	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4248.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4250.7	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4251.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4254.7	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4254.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4256.3	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4257.6	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4258.6	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4259.4	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4260.5	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4260.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4266.9	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4270.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4271.4	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4274.0	0.0	0.000	-11.250	1.000	0.000	-8.160	0
4275.8	0.0	0.000	-11.250	1.000	0.000	-8.160	0

arithmetic mean of strike values (col 2) = 234.0 Total measurements taken = 14

Feature Orientation measurements **Well: Mobil Pincher Creek 16-13-3-29W4 Chatter Fractures**

Reference Mardia 1972 for statistics of directional data

Total Sin x thick	Total Cos x thick	Total Thickness	S Col A/ColC	C ColB/ColC	R x R	R	S/R	C/R	Azimuth from S/R	Azimuth from C/R	Standard Deviation
-11.25	-8.16	14	-0.8036	-0.5829	0.9854	0.9927	-0.8095	-0.5871	234.0	234.0	6.9

Well Name: Mobil Pincher Ck 16-13-3-29W4							
Bedding							
Depth KB m	Strike Azi of feature	Sin Azi	Cumulative Total Sin Azi	Cos Azi	Cos Azi corrected for zero values	Cumulative Total Cos Azi	Measurement made or not 1 or 0 entered
4051.3	151.6	0.476	0.476	-0.880	-0.880	-0.880	1
4056.2	0.0	0.000	0.476	1.000	0.000	-0.880	0
4058.7	198.4	-0.316	0.160	-0.949	-0.949	-1.829	1
4089.7	159.7	0.347	0.507	-0.938	-0.938	-2.766	1
4091.5	126.2	0.807	1.314	-0.591	-0.591	-3.357	1
4093.4	132.9	0.733	2.046	-0.681	-0.681	-4.038	1
4100.3	146.1	0.558	2.604	-0.830	-0.830	-4.868	1
4102.8	0.0	0.000	2.604	1.000	0.000	-4.868	0
4104.0	0.0	0.000	2.604	1.000	0.000	-4.868	0
4104.6	0.0	0.000	2.604	1.000	0.000	-4.868	0
4104.9	0.0	0.000	2.604	1.000	0.000	-4.868	0
4113.8	145.7	0.564	3.168	-0.826	-0.826	-5.694	1
4114.2	0.0	0.000	3.168	1.000	0.000	-5.694	0
4120.3	0.0	0.000	3.168	1.000	0.000	-5.694	0
4120.8	0.0	0.000	3.168	1.000	0.000	-5.694	0
4121.9	146.4	0.553	3.721	-0.833	-0.833	-6.527	1
4125.7	142.9	0.603	4.324	-0.798	-0.798	-7.324	1
4141.1	242.7	-0.889	3.436	-0.459	-0.459	-7.783	1
4172.2	155.7	0.412	3.847	-0.911	-0.911	-8.694	1
4183.6	128.1	0.787	4.634	-0.617	-0.617	-9.311	1
4184.0	0.0	0.000	4.634	1.000	0.000	-9.311	0
4184.3	0.0	0.000	4.634	1.000	0.000	-9.311	0
4184.4	0.0	0.000	4.634	1.000	0.000	-9.311	0
4184.7	0.0	0.000	4.634	1.000	0.000	-9.311	0
4185.6	152.0	0.469	5.104	-0.883	-0.883	-10.194	1
4186.2	0.0	0.000	5.104	1.000	0.000	-10.194	0
4186.6	0.0	0.000	5.104	1.000	0.000	-10.194	0
4186.7	0.0	0.000	5.104	1.000	0.000	-10.194	0
4187.0	0.0	0.000	5.104	1.000	0.000	-10.194	0
4187.1	179.6	0.007	5.111	-1.000	-1.000	-11.194	1
4187.5	197.7	-0.304	4.807	-0.953	-0.953	-12.147	1
4193.3	214.8	-0.571	4.236	-0.821	-0.821	-12.968	1
4197.2	159.8	0.345	4.581	-0.938	-0.938	-13.907	1
4198.9	168.5	0.199	4.780	-0.980	-0.980	-14.887	1
4201.9	165.7	0.247	5.027	-0.969	-0.969	-15.856	1
4203.8	210.3	-0.505	4.523	-0.863	-0.863	-16.719	1
4208.3	136.8	0.685	5.208	-0.729	-0.729	-17.448	1
4208.8	194.3	-0.247	4.961	-0.969	-0.969	-18.417	1
4212.1	134.8	0.710	5.670	-0.705	-0.705	-19.122	1
4213.1	164.5	0.267	5.937	-0.964	-0.964	-20.085	1
4213.2	164.5	0.267	6.205	-0.964	-0.964	-21.049	1
4213.7	150.7	0.489	6.694	-0.872	-0.872	-21.921	1
4215.8	139.9	0.644	7.338	-0.765	-0.765	-22.686	1
4218.8	144.7	0.578	7.916	-0.816	-0.816	-23.502	1
4220.0	140.8	0.632	8.548	-0.775	-0.775	-24.277	1
4220.5	133.9	0.721	9.269	-0.693	-0.693	-24.970	1
4221.6	136.9	0.683	9.952	-0.730	-0.730	-25.701	1
4222.5	137.4	0.677	10.629	-0.736	-0.736	-26.437	1
4223.0	144.2	0.585	11.214	-0.811	-0.811	-27.248	1
4223.3	138.3	0.665	11.879	-0.747	-0.747	-27.994	1
4225.3	121.1	0.856	12.735	-0.517	-0.517	-28.511	1
4226.3	203.8	-0.404	12.332	-0.915	-0.915	-29.426	1
4226.8	132.5	0.737	13.069	-0.676	-0.676	-30.101	1

4227.9	142.9	0.603	13.672	-0.798	-0.798	-30.899	1
4230.5	167.7	0.213	13.885	-0.977	-0.977	-31.876	1
4231.0	153.3	0.449	14.334	-0.893	-0.893	-32.769	1
4232.1	156.9	0.392	14.727	-0.920	-0.920	-33.689	1
4232.2	147.4	0.539	15.266	-0.842	-0.842	-34.532	1
4232.4	131.4	0.750	16.016	-0.661	-0.661	-35.193	1
4232.6	168.7	0.196	16.212	-0.981	-0.981	-36.174	1
4233.2	150.5	0.492	16.704	-0.870	-0.870	-37.044	1
4235.5	142.4	0.610	17.314	-0.792	-0.792	-37.836	1
4235.7	165.4	0.252	17.566	-0.968	-0.968	-38.804	1
4236.7	149.5	0.508	18.074	-0.862	-0.862	-39.666	1
4237.6	128.6	0.782	18.855	-0.624	-0.624	-40.289	1
4237.8	122.8	0.841	19.696	-0.542	-0.542	-40.831	1
4238.8	166.3	0.237	19.933	-0.972	-0.972	-41.803	1
4240.1	140.0	0.643	20.575	-0.766	-0.766	-42.569	1
4240.5	129.7	0.769	21.345	-0.639	-0.639	-43.208	1
4241.9	159.4	0.352	21.697	-0.936	-0.936	-44.144	1
4242.3	172.9	0.124	21.820	-0.992	-0.992	-45.136	1
4243.1	158.1	0.373	22.193	-0.928	-0.928	-46.064	1
4245.0	158.5	0.367	22.560	-0.930	-0.930	-46.994	1
4246.2	158.7	0.363	22.923	-0.932	-0.932	-47.926	1
4248.2	163.3	0.287	23.210	-0.958	-0.958	-48.884	1
4248.6	148.1	0.528	23.739	-0.849	-0.849	-49.733	1
4248.9	151.2	0.482	24.221	-0.876	-0.876	-50.609	1
4250.7	167.9	0.210	24.430	-0.978	-0.978	-51.587	1
4251.3	162.1	0.307	24.738	-0.952	-0.952	-52.538	1
4254.7	153.3	0.449	25.187	-0.893	-0.893	-53.432	1
4254.9	158.6	0.365	25.552	-0.931	-0.931	-54.363	1
4256.3	160.7	0.331	25.882	-0.944	-0.944	-55.307	1
4257.6	141.3	0.625	26.508	-0.780	-0.780	-56.087	1
4258.6	144.7	0.578	27.085	-0.816	-0.816	-56.903	1
4259.4	150.5	0.492	27.578	-0.870	-0.870	-57.774	1
4260.5	139.7	0.647	28.225	-0.763	-0.763	-58.536	1
4260.9	153.8	0.442	28.666	-0.897	-0.897	-59.433	1
4266.9	151.6	0.476	29.142	-0.880	-0.880	-60.313	1
4270.8	123.9	0.830	29.972	-0.558	-0.558	-60.871	1
4271.4	146.2	0.556	30.528	-0.831	-0.831	-61.702	1
4274.0	117.5	0.887	31.415	-0.462	-0.462	-62.164	1
4275.8	225.8	-0.717	30.698	-0.697	-0.697	-62.861	1

arithmetic mean of strike values (col 2) =

154.9

Total measurements taken =

76

Feature Orientation measurements **Well: Mobil Pincher Creek 16-13-3-29W4 Bedding**

Reference Mardia 1972 for statistics of directional data

Total Sin x thick	Total Cos x thick	Total Thickness	S Col A/ColC	C ColB/ColC	R x R	R	S/R	C/R	Azimuth from S/R	Azimuth from C/R	Standard Deviation
30.698	-62.861	76	0.4039	-0.8271	0.8473	0.9205	0.4388	-0.8986	154.0	206.0	23.3

