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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

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GEOLOGY OF THE TEST ENTRY, A-NORTH MINE, MICHEL, BRITISH COLUMBIA

BY

D. K. NORRIS

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Terms of Reference

At the request of the Director of the Mines Branch, Department of Mines and Technical Surveys, the writer made a detailed study of the geology in and around the test entry* being driven in A-North Mine, Michel, British Columbia, with a view to assessing the relationship between the rock fabric and the type of roof support that might be used safely and economically within the domain of that mine.

Chronology

The entry was begun with the continuous miner on three shifts on October 22, 1963 and completed November 1. No work was done on the weekend of October 26-27. Prior to completing the inbye half, the entry was connected by a slant with the belt road (See Figure 1). A second connection about 65 feet from the face was made on November 6, five days after completion of the entry. Geological studies were conducted between November 6 and 8, 1963.

Acknowledgements

The writer wishes to express his appreciation to the following personnel of the Crow's Nest Pass Coal Company for helpful discussions and assistance underground: J. E. Morris, Resident Manager; L. Dworkin, chief engineer; V. Hulbert, pit boss;

* Hereafter referred to as 'the entry'.

H. Chamberlain, engineer; J. Crabb, geologist; S. Hughes, fireboss; and J. Whittaker, overman. Their keen interest in the progress of the study and in the writer's safety are deeply appreciated.

Geological Setting

The A-North Mine is in A seam, approximately 400 feet stratigraphically below the top of the Jura-Cretaceous Kootenay Formation. The seam may be as much as 22 feet thick (Newmarch, 1953, p. 92), although it is known to thin to as little as 6 inches in some parts of A-North Mine.

The workings occur in south-dipping beds of the *en echelon* fold system in Mesozoic rocks of the Fernie Basin. Faulting at the stratigraphic level of A seam is for the most part limited to detachment surfaces at the top and bottom of the coal seam, to extension and contraction faults with stratigraphic separations of a few inches and to differential movement of a few inches on joint surfaces ("joint-faults") in directions ranging from parallel to perpendicular to the stratigraphic layering. Extension faults predominate.

The primary depositional fabric of the coal seam has been largely destroyed through shear consequent upon interstratal slip. Shear surfaces and drag-folds in the coal, although not indicative of a consistent kinematic pattern, confirm a relative eastward motion of roof over coal and of coal over floor in the area of the mine. Lineations on roof and floor, moreover, trend easterly and on the average parallel the strike of the coal seam. These data are incompatible with an up dip motion of hanging-wall beds with respect to foot-wall and may well support Crabb's suggestion (1957, p. 83) of an eastward bodily transport of the Fernie Basin.

Pinching and swelling of A seam appears to be a tectonic rather than a depositional phenomenon (J. Crabb, personal communication, 1963). Areas where the seam is thin are unpredictable in occurrence and in some instances at least were observed to be in association with local shortening of the floor or roof along contraction faults. Such faults are commonly, but not always, traceable from the floor or roof through the coal into their counterparts on the opposite side of the seam. The fact that extension faults on the other hand are rarely traceable across the seam would suggest that within the area of observation extension faults are in general older and have been offset on detachment surfaces at the coal-rock interface as a consequence of interbed slip.

Polished and striated bedding surfaces observed within a few feet of the roof and floor of the seam indicate moreover that interbed slip was not limited to coal-rock interfaces but that it must have taken place for some stratigraphic interval on either side. A thin, highly sheared rider seam occurs within a stratigraphic interval of 20 feet of A seam. It is a detachment zone, allowing heavy roof conditions and ultimate collapse of the strata between it and A seam in areas where more than about 60 per cent of the coal support has been removed.

Natural jointing in the roof and floor rocks pervades the area of the mine. In order to assess the possibility of a joint subfabric common to the entry and to other areas of the mine, two locations were selected along No. 1 Level, Location I approximately 2,500 feet outbye of the entry and Location II approximately 1,500 feet outbye (Figure 1). In both instances joint measurements were made in the first two to three feet of floor rock in areas where A seam had been tectonically thinned and the subjacent strata had been brushed. The joints commonly ranged from perpendicular to subperpendicular to the layering, a feature characteristic of pre-Laramide, systematic joints. They have undergone external rotation as a consequence of the Laramide deformation. A few dip as little as 60 degrees to the layering and may well be tectonic in origin.

The joint subfabric diagrams have been contoured according to the method proposed by Kamb (1959, pp. 1908-1909) in order that orientations of joint surfaces of statistical significance may be ascertained. The area A of the counter used in the conventional (Schmidt) contouring method is so chosen that if the population N lacks preferred orientation, the number of points E expected to fall within the area A is one times the standard deviation $\sigma(E)$ of the number of points n that will actually fall within the area for random sampling i. e. $\sigma(E)/E = 1$. The expected density E of joint poles for no preferred orientation is therefore $1 \times \sigma(E)$ and areas within the 3 $\sigma(E)$ contour say, are likely to be significant.

Two joint sets predominate at Location I (Figure 2), the one with a mean attitude of 285°, 75° NE, the other 013°, 80° NW for beds with an attitude of 297°, 17° SW. Both sets consist predominantly of planar surfaces with spacings ranging from 3 to 12 inches.

Joints at Location II on the other hand are not readily divisible into principal sets although from Figure 3 it is apparent that there is a preferred orientation of surfaces with an attitude of 335°, 80° NE for beds with an attitude of 285°, 15° SW. Scattered poles in the lower part of the diagram have approximately the same orientation as the set at Location I which strikes 285°. There is however no positive correlation of joint sets between these two stations.

Geology of the Entry

A geological sketch map of the roof of the entry on a scale of one inch to 10 feet was prepared (Figure 4) from observations taken November 5 and 6, four and five days respectively after the entry was completed. Ten-foot intervals were marked on the timber supports of the low side of the entry, with the zero point arbitrarily set at the first wooden support next to the face. From there observations were made over a 524-foot interval with the location of joints, faults and other features being estimated to the nearest one foot. A Brunton pocket transit was used to measure azimuth and dip readings and a protractor to measure pitch of lineations on shear surfaces. Azimuth readings are believed accurate to within 5 degrees, and dips of surfaces and pitches of lineations to within less than 5 degrees.

The attitude of the roof rock in the entry averages 280°, 18° SW, with measured strikes ranging between about 270° and 290°, and dips between 11° and 24° SW. The entry trends approximately parallel to the strike.

The principal pre-mining features observed in the entry were joints, bedding detachment surfaces in the roof, faults in the roof and/or floor, and shear surfaces and drag-folds in the coal. The coal in the area of the test entry averages about 12 feet thick although it was observed to thin to as little as about 7 feet between 500 and 520 feet from the face where the floor rock was exposed. There the floor was highly polished indicating detachment of the coal but it lacked slickenside striae from which to establish the latest relative motion of coal and floor.

Local caving and opening of cracks in the roof permitted the measurement of attitudes of joints or sets of joints at many locations.

The joints are represented symbolically in Figure 4 and poles to their surfaces in Figure 5. Although the scatter is large, there would appear to be three orientations of statistical significance. They are: 350°, 90°; 010°, 90°; and 285°, 85° NE. The latter two are nearly identical with the principal sets at Location 1.

The joints are for the most part planar surfaces perpendicular and subperpendicular to layering. They commonly continue through one or more beds. A few are slickensided because of microscopic differential movement parallel to them. In some instances, however, joint-faults with measurable stratigraphic separation have developed along them (Plate P1). Of secondary importance are curviplanar, slickensided and striated surfaces with no measurable separation in the direction of the striae. They would appear to be kinematically and dynamically related to extension faults.

In many instances it was possible to examine polished and striated bedding interfaces where roof rock had been scaled prior to the placing of supports, as well as where the immediate roof had subsequently failed. There, shale beds commonly ranged from one to 6 inches thick and their interfaces have been detached through inter-bed slip.

Faults observed in the entry consisted of extension and contraction surfaces as well as surfaces essentially perpendicular to the layering ("joint-faults"). Extension faults predominate and stratigraphic separations greater than 7 inches were not observed. Joint-faults commonly occur in swarms of subparallel surfaces along each of which the separation is less than one inch but for the swarm as a whole could amount to several inches. At 25 to 30 feet from the face of the entry for example, a series of such parallel joint-faults was observed to lie essentially perpendicular to the layering, to have an average spacing of 8 inches in the plane of the layering and to have the downdropped side consistently inbye. They have an average stratigraphic separation of about one inch, with none exceeding 1½ inches. About the middle of the entry they are intersected by a second series of parallel faults with spacing ranging from 4 to 6 inches, stratigraphic separation averaging ½ inch and with none exceeding 3/4 inch . These latter faults also have the downthrown side inbye. They are represented symbolically by one fault of each type in Figure 4.

Poles to these slip surfaces are included in Figure 5 with the direction of slickenside striae. These directions are segments of great circles through the tangent point of the slip surfaces with the lower hemisphere of the Schmidt net and the intersection of their respective lineations with this hemisphere. (Hoeppener, 1955, pp 37, 38). The arrowheads indicate the direction of relative motion of hanging-wall beds. Those faults which result in a shortening of the strata in a direction perpendicular to the trace of the fault on the layering (contraction faults) must therefore be indicated by arrows pointing radially outwards; faults which permit an elongation of the strata on the other hand will be indicated by arrows pointing radially inwards. Striated, curviplanar joints necessarily have no measurable relative motion of one side parallel to the other. Their striae are therefore represented in Figure 5 by segments of great circles without arrowheads.

Those faults examined in the entry were rarely traceable into the coal and were never traceable into foot-wall beds by virtue of the fact that the foot-wall was exposed only in one small area.

The extension fault at 500 feet however was not seen to cut foot-wall strata. It presumably died out downwards in the coal or was offset from its counterpart in the floor through interbed slip after the fault was formed.

It is evident from Figure 5 that extension faults have attitudes significantly different from joints. They lie mainly in hkl and therefore do not appear to be related dynamically to the local stress system which gave rise to interbed slip and deformation within the coal. None of the faults examined was observed to have opened up as a consequence of subsidence of the strata into the mine cavity.

A few hairline cracks with irregular trace in the plane of the immediate roof were noted, as for example at 193 and 247 feet from the face. They do not appear to be joint controlled and their depth is unknown. Such cracks across the entry are few and those parallel to it are rare.

The coal on either side of the entry is highly sheared, commonly with the primary depositional fabric totally destroyed (Plate P2). Drag-folds and shear surfaces within it, here as elsewhere in the mine, indicate a preferred eastward direction of relative motion of the roof with respect to the coal and of the coal with respect to the floor. This motion is supported moreover by the direction of lineations observed on the roof of the entry (Figure 4). The prevalence of polish at the interfaces of the coal with roof and floor rock indicates that there has been regional detachment of the coal from adjacent strata. The coal therefore falls free of the roof when it is undermined and cannot be relied upon to support itself.

Post-mining Adjustments

Relaxation of coal and rock into the entry occurs in conjunction with and consequent upon the mining of coal. Within four days of completion of the entry the shape of the high and low side ribs was noticeably altered through relaxation and sloughing. Although A seam is structurally weak it was evident that the pillars on either side of the entry were carrying much of the redistributed load; roof bolts adjacent to the ribs in general showed little evidence of taking weight.

The rider seam is known from three boreholes located 1,000 to 1,500 feet from the entry to occur between 7 and 8 feet above the top of A seam. It may therefore be just beyond the reach of the 7-foot bolts in the entry. Its close proximity may be responsible in part for the almost immediate sag and local collapse of roof strata.

Local collapse of the immediate roof occurred as mining progressed and required scaling in some instances of as much as two feet of strata prior to the placing of timbers and roof bolts. This was especially apparent where the slant intersected the entry between 270 and 300 feet from the face. There heavy roof conditions prevailed and from one to two feet of immediate roof had been removed. Joints and polished bedding surfaces were exposed in abundance. Similar but less extensive occurrences were noted elsewhere in the entry and their outlines have been included in Figure 4.

Cracks, in some instances open as much as $\frac{1}{4}$ inch, were noted at several points in the immediate roof. They commonly followed planar and curviplanar joints; rarely did they cut indiscriminately across them as for example 193 feet from the face. The latter appear to be the result of tensile failure of the roof shale and not simply the result of the opening of (pre-mining) joints. Seepage of meteoric waters was commonly associated with heavy roof conditions in both bolted and unbolted ground.

Visual manifestations of relaxation of the lowest six feet of roof strata into the mine cavity were also evident in the squeezed and shattered condition of some of the 2-inch by 12-inch planks at the roof bolt installations. Characteristically the strata about the middle two bolts appear to be placing the most weight on the planks (See Plate P3). The 10- to 12-inch diameter timber supports on the other hand commonly show little evidence of the load they must be carrying. They have their footings in coal however so that they are free to sink into this relatively weak material as the load on them increases.

Collapse of the lowermost $1\frac{1}{2}$ feet of roof rock 180 feet from the face occurred during the weekend of November 2 - 3, 1963. It was reported that the timbers did not break from overload but rather that they rotated out of position. The joint-outlined cavity resulting from this failure is shown in Plate P4 and the disaggregated, thin-bedded, jointed blocks of the debris in Plate P5.

Conclusions

Joints and bedding surfaces play a fundamental role in the relaxation and ultimate collapse of the roof rock into the mine. The shape, extent and depth of the cavities resulting from the removal and collapse of roof rock is dictated by the local fracture array and the spacing of bedding interfaces.

From the preferred directions of joint sets in the roof of the entry it is apparent that the slants may be more favourably oriented for minimum movement of roof rock into the mine cavity.

Their direction approximately bisects the obtuse angle between the principal joint sets. A comparative study of roof sag in the entry and connecting slants is suggested.

Wooden planks installed with the roof bolts commonly show early signs of relaxation of roof rock into the mine cavity and in this respect are more sensitive than the standard timber support, especially where the latter have their footings in coal.

Heavy roof conditions were noted in areas where the roof is now supported by bolts and timber as well as where the roof is supported by timber alone. The reliability of bolts as a means of supporting the roof can only be established when the timber installed in conjunctión with the bolts is removed.

References

Crabb, J.

1957: A Summary of the Geology of the Crowsnest Coal Fields and Adjacent Areas; Alberta Soc. Petrol. Geol., Seventh Annual Field Conference, pp. 77-85.

Hoeppener, R.

1955: Tektonik Im Schiefergebirge; Geol. Rdsch., pp. 26-58, 11 figs.

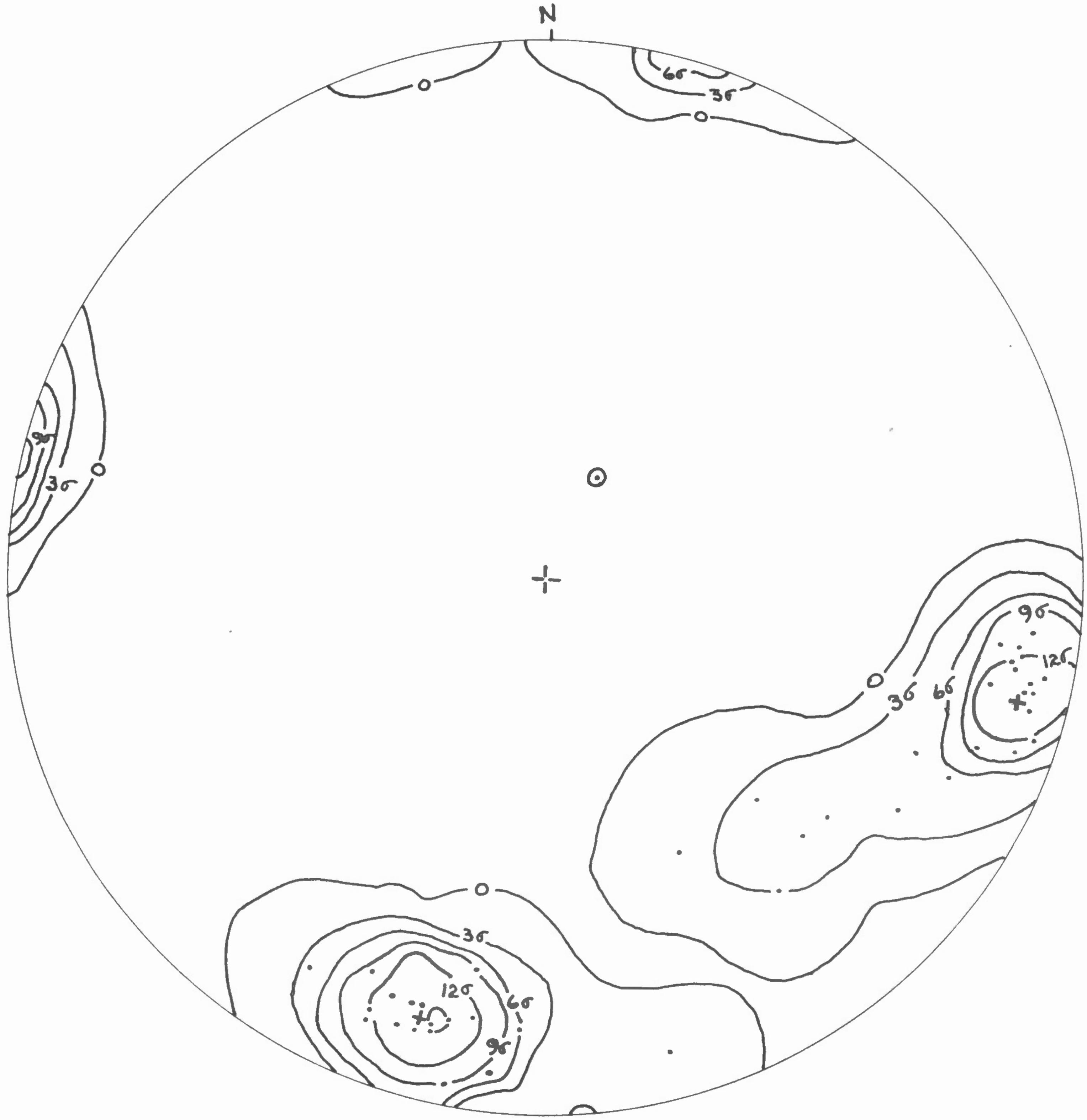
Kamb, W. B.

1959: Ice Petrofabric Observations from Blue Glacier, Washington, in Relation to Theory and Experiment; J. Geophys. Research, vol. 64, no. 11, pp. 1891-1909, 15 figs.

Newmarch, C. B.

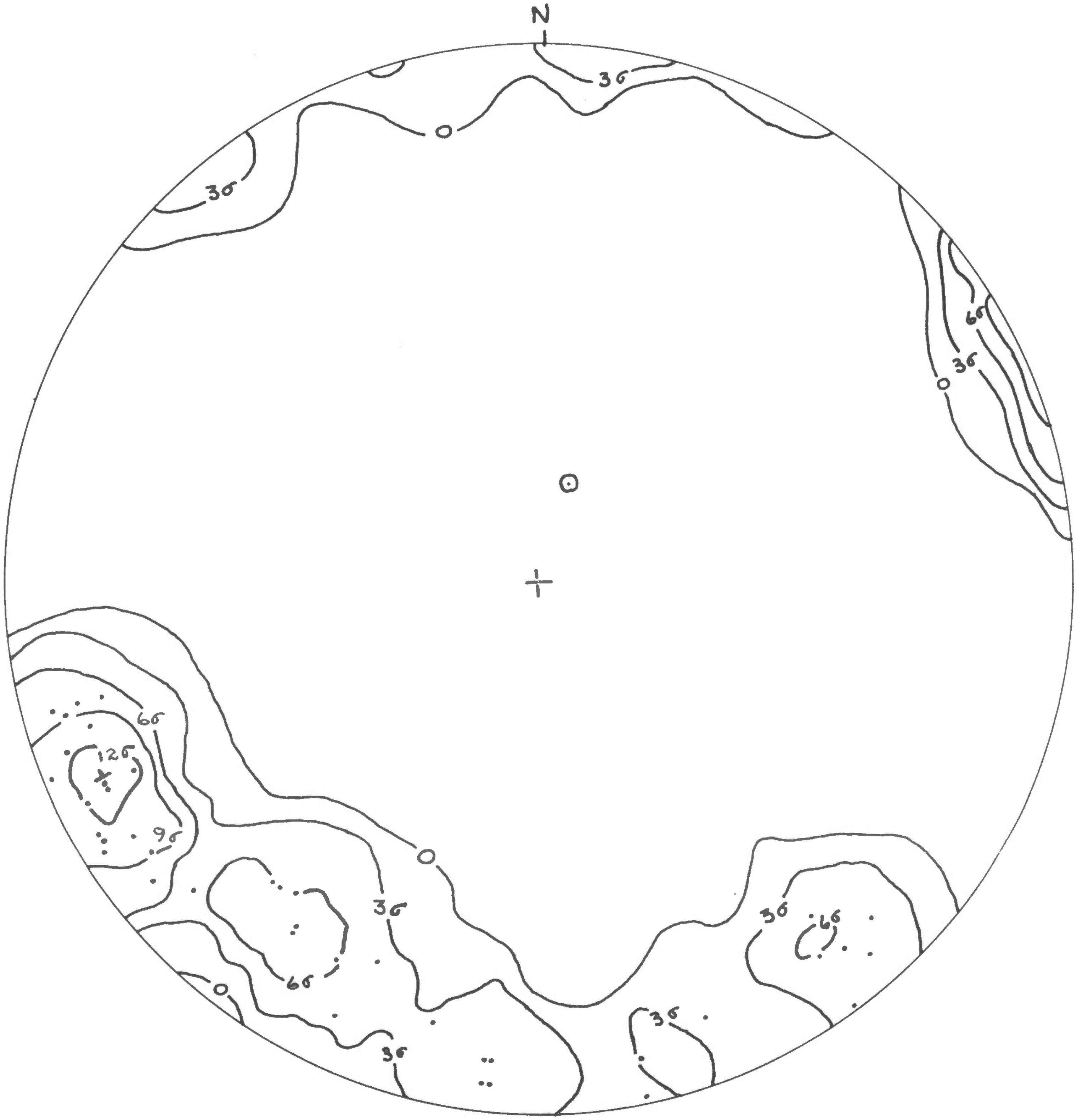
1953: Geology of the Crowsnest Coal Basin, with special reference to the Fernie Area; Dept. Mines, Bull. 33, 19 figs., 7 pls.

Figure 2
Joint subfabric, A-North Mine
Location I



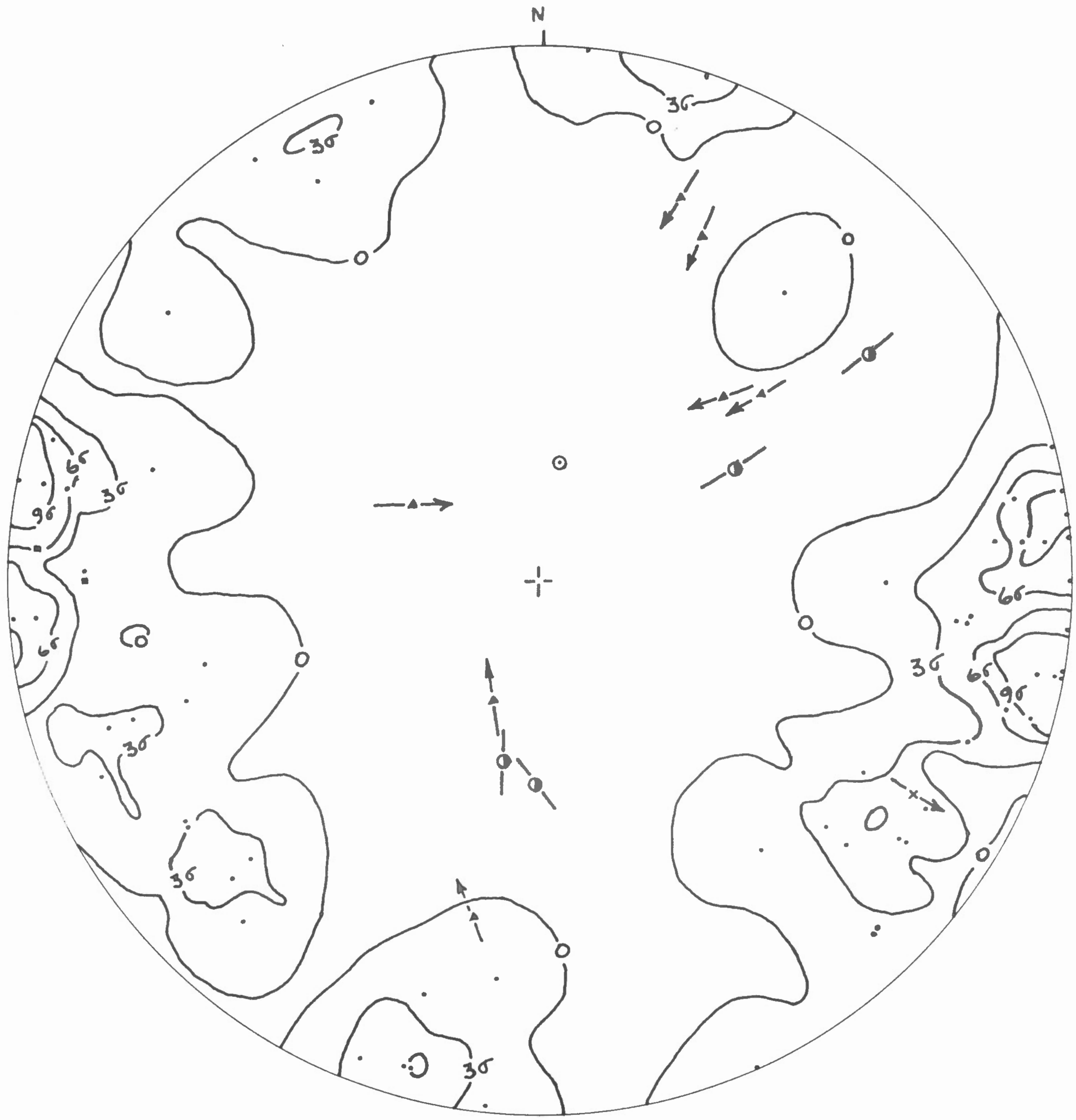
Bedding ⊙
N = 40
σ(E)/E = 1   A = 0.024   Contours at 0, 3σ, 6σ, 9σ, 12σ, 15σ

Figure 3
Joint subfabric, A-North Mine
Location II



Bedding ⊙
N = 40
σ(E)/E = 1   A = 0.024   Contours at 0, 3σ, 6σ, 9σ, 12σ

Figure 5
Fracture Fabric, A-North Mine
Test Entry



Joints, 62 poles
Joint-faults, 2 poles
Extension faults, 7 poles
Shear surfaces with no strat. separation, 4 poles
Contraction faults, 1 pole
Bedding
Slip linears; relative motion known

Contours for joint poles at 0, 3σ, 6σ, 9σ
N = 62 σ(E)/E = 1 A = 0.016

Plate P1

"Joint-faults" in roof of A seam, 25 feet from face of test entry.

D.K.N. 11-11-63

Plate P2

West-dipping shear surfaces in coal at face of test entry, November 5, 1963.

D.K.N. 11-7-63

Plate P3

Crushed plank at third roof bolt from low side of test entry, 225 feet from face, one week after installation.

D.K.N. 12-5-63

Plate P4

Joint-controlled cavity in roof, 180 feet from face of test entry; timber in lower right is approximately 10 inches in diameter.

D.K.N. 12-4-63

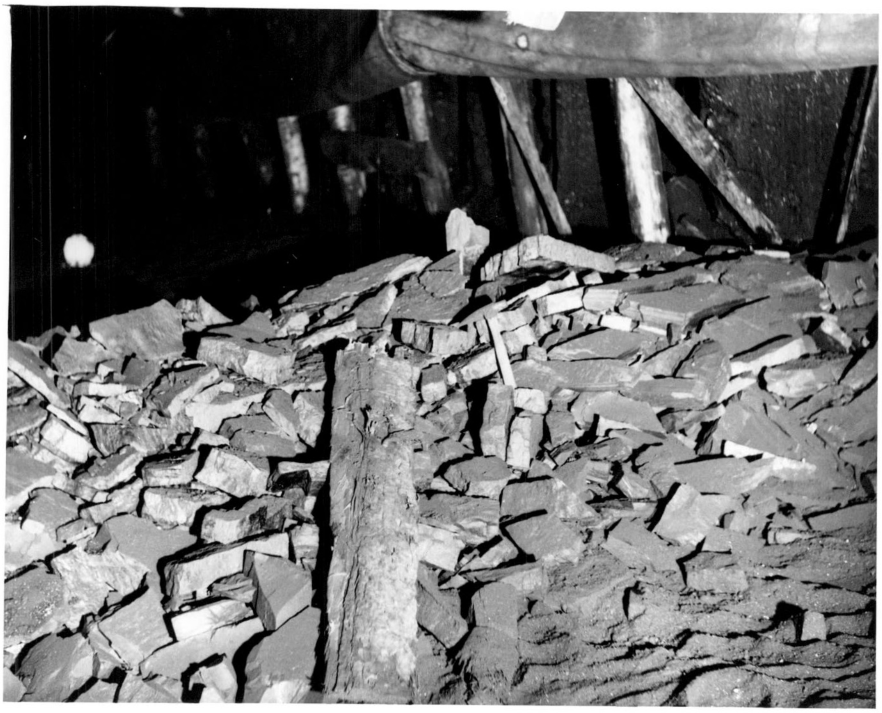


Plate P5

Joint-controlled debris from roof fall,
180 feet from face of test entry.

D.K.N. 12-1-63