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# 1982/11. Structural geology of the Mt Bischoff Precambrian rocks

*by P.R. Williams*

*Abstract*

The rocks at Mt Bischoff which host the economically important cassiterite ore bodies have been deformed during four deformation events. These events produced mesoscopic folds with highly variable hinge directions and complex styles. The first deformation event resulted in overturning of a large part of the succession, and also produced tight to isoclinal folds, detached fold cores and in places an intense axial cleavage parallel to the bedding. The second event produced folds controlled by the bedding and cleavage anistropy, resulting in asymmetrical conjugate fold patterns. Folds of this phase vary from tight to open in style. The third(?) phase folded the earlier bedding into a large antiformal flexure which now defines the bedding plane geometry of the mountain. It caused rotation of axial surfaces of second phase folds. Minor folds associated with this structure vary from upright flexural-slip folds to conjugate folds and kink-bands. The fourth(?) phase produced mesoscopic upright folds trending NNE, but did not produce major folds.

## INTRODUCTION

Structural interpretation of the Mt Bischoff sequence of rocks has been confused. Several interpretations of both mesoscopic and macroscopic structures have been put forward (Knight, 1953; Groves and Solomon, 1964; Groves, 1968, Groves *et. al.* 1972; Anderson and Hopwood, 1963; Lambert, 1969; Fitch, 1970), involving the interpretation of the major structure controlling the area as an anticlinonium with superimposed folds producing the varied (but unexplained) fold hinge orientations. No detailed analysis of orientation data was attempted by these authors, although Chappell (1971) divided the region into several structural domains. The connection between these domains was not established. The current study of the Mt Bischoff structure was undertaken as part of a regional geological mapping project encompassing the whole of the Valentines Peak Quadrangle (1:50 000 geological map, in prep.), and consequently map scale was not always adequate for detailed interpretations of rock distribution, which are available from Groves (1968) and Comstaff Pty Ltd (open file reports, Tasmania Department of Mines).

The method of analysis used here in determining the structural history is based on evidence of superposition of events, including cleavage overprinting, spatial analysis of the orientation of separate fold elements, and the development of accurate geological cross-sections.

## STRUCTURAL HISTORY

### *First tectonic deformation event*

The earliest tectonic folds in the area are isoclinal refolded folds, described in detail by Groves (1971) and reproduced in Groves, *et al.* (1972). Diagrams in these papers clearly show the effects of superposition of later folds on the early isoclinal structures which produces complex interference patterns. Groves and Solomon (1964) also report isoclinal folding and suggest that they are tectonically insignificant. This opinion is reiterated by Groves in Groves *et al.* (1972), despite the use of these early structures to make structural comparison between the Mt Bischoff

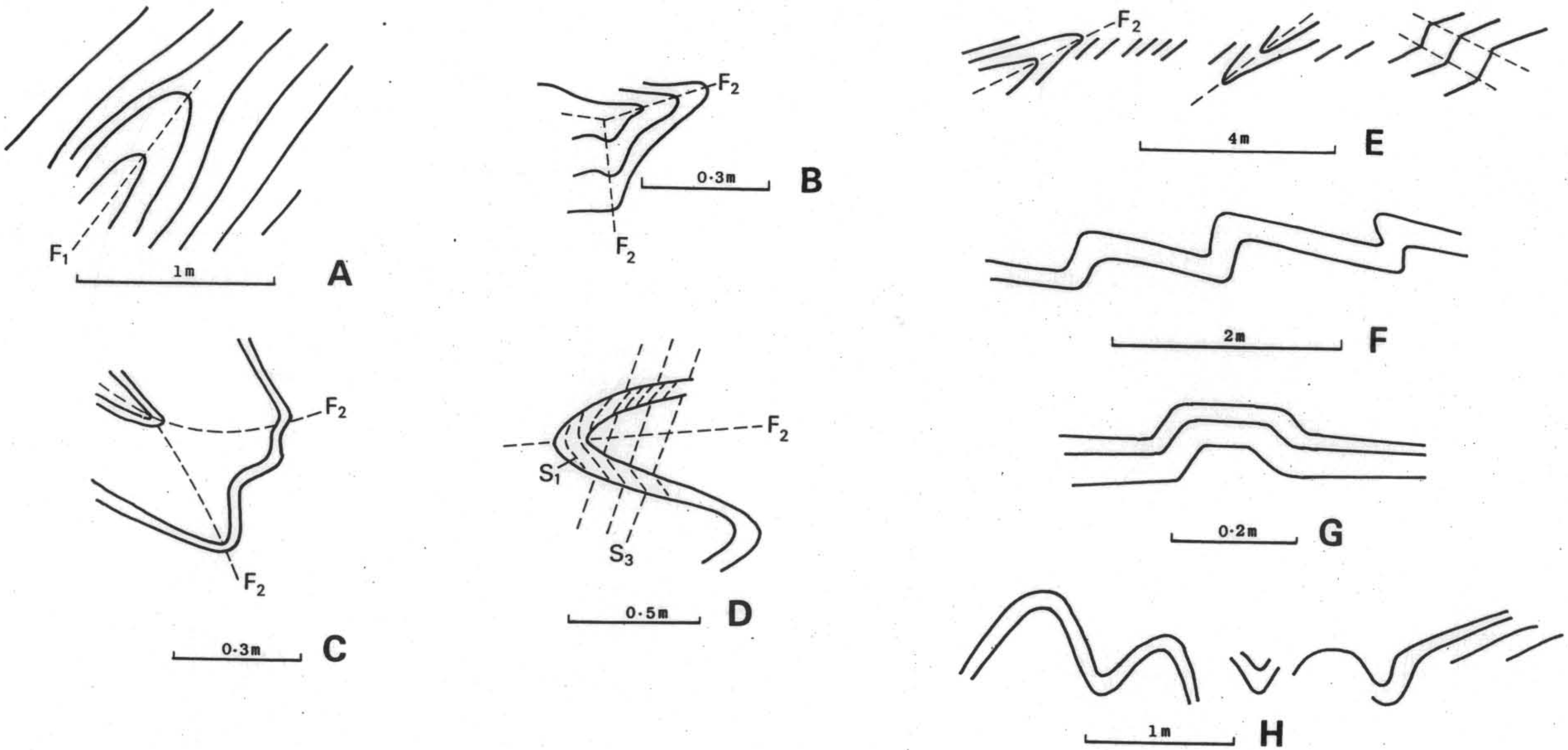
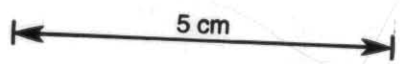



Figure 1. *Mesoscopic fold styles at Mt Bischoff. A: Isolated isoclinal fold cores in phyllite; B: F2 conjugate fold (from Groves, 1971); C: F2 conjugate fold; D: Cleavage relationship within F2 fold; E: Typical F2 fold profile - fold hinge lines are typically non-parallel; F,G,H: F3 fold styles.*



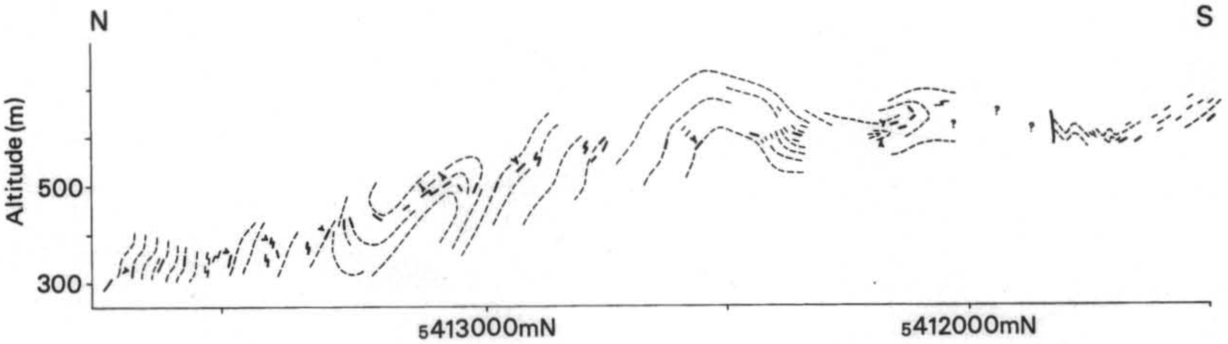
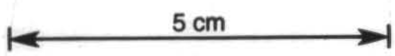



Figure 2. *Accurately constructed profile section. Apparent dip of actual readings projected onto the section line indicated by heavy lines. Section is vertical, looking due east along state grid line 376000mE. V/H = 1.*



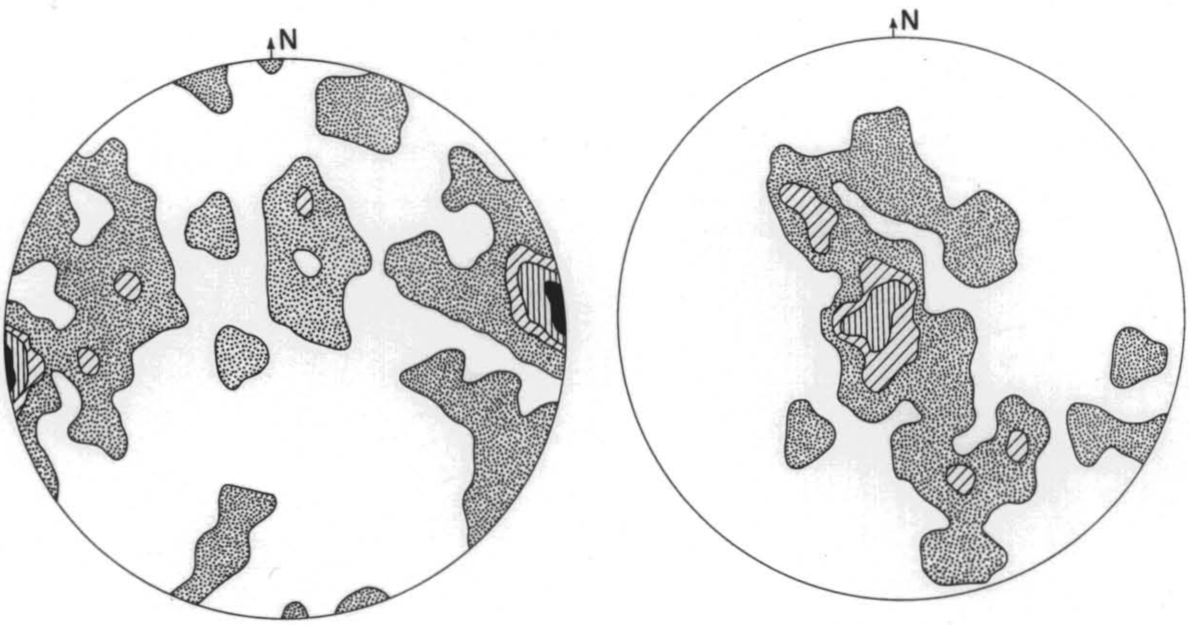




Figure 3. *A: Orientation of all fold hinge lines from west of Mt Bischoff summit. Lower hemisphere equal area projection of 56 values contoured at 1, 5, 7, 11% per 1% area.*

*B: Orientation of F2 axial surfaces from west of Mt Bischoff summit. Lower hemisphere equal area projection of poles to surfaces contoured at 1, 6, 10% per 1% area.*

series and the overlying rocks (Groves, 1971). Lambert (1969) and Fitch (1970) report inverted drag folds and use these to infer that a large part of the sequence is overturned. This conclusion is not supported by Groves in Groves *et al.* (1972).

Early tight to isoclinal folds are abundant throughout the area, and are similar in form to those described from Don Hill (Groves, 1971). In addition isolated fold cores in phyllite are present, and there is a very well developed cleavage sub-parallel to bedding related to these folds over much of the Mt Bischoff region (fig. 1). In addition, the dominant E-W trending vertical cleavage is a spaced crenulation cleavage produced by deformation of the earlier, shallowly dipping cleavage surface related to the isoclinal folds. In the profile section of the western side of Mt Bischoff (fig. 2) a macroscopic S-fold preserved between steeply northerly dipping surfaces is inferred to be an F1 fold because it is unrelated in style to the major Mt Bischoff monocline and associated minor folds have the earliest cleavage as their axial surface cleavage. Mesoscopic isoclinal folds exposed in a quarry on the road to the PMG towers on Mt Bischoff summit are also related to major inversion of sedimentary facing and it is proposed that a macroscopic F1 fold is present in that area.

Evidence of sedimentary facing in the Mt Bischoff series is sparse, but ripple-marks, cross-bedding and graded-bedding are present at various localities, and water-escape structures such as dish structure and convolute folds have all been used to determine facing. Sedimentary facing at various localities on the road to the North Valley workings unequivocally indicates that the beds are overturned. The presence of the major S-fold would therefore indicate that this section of Mt Bischoff is on the lower limb of a south-facing recumbent to reclined anticline. The opposite direction of fold facing inferred by Lambert (1969) and Fitch (1970) may be the result of inferring fold facing from F1 folds rotated during D2. Unfortunately there is insufficient sedimentary facing evidence and incomplete preservation of unrotated D1 folds to allow profiles of F1 folds to be established on either vergence or cleavage/bedding criteria. Significantly, the sedimentary facing in the Waratah River section suggests that the beds are dominantly upright, which may indicate that the sequence there is on the opposite limb of an F1 structure. This has not been confirmed by the orientation of F1 mesoscopic folds and S1 cleavages.

*Second folding event*

The second folding event is characterised by the development of conjugate fold styles of varying geometry, and only a weak cleavage development. F2 fold styles are shown in Groves (1971) and Figure 1, B-E. The varied form of the conjugate folds associated with the D2 event are explained by the application of a stress field at an angle to the dominant anisotropy caused by the bedding and the cleavage formed during D1. That the two fold sets, the very open folds and the tight folds which fold a cleavage (fig. 1, D) belong to the same conjugate system is shown by the convergence of axial planes into a single surface (fig. 1, C) and the highly variable hinge-line orientation of these folds. F2 folds are the most abundant mesoscopic structures at Mt Bischoff, but are essentially co-axial with later F3 folds. The plot of fold hinge-line orientation data on the North Valley road (fig. 3, A) shows the wide scatter of points, with a concentration in an east-west direction. This plot includes F3 folds which are more strongly directionally oriented.

Although the hinge lines of the F2 folds are variably oriented, axial surface directions are more tightly grouped and lie on a great circle, the pole of which coincides with the overall statistical hinge direction (fig. 3, B). The axial surface directions of D2 conjugate fold sets vary according to the dip of external bedding, which defines the overall fold pattern of the Mt Bischoff area. A diagram showing the position of axial surfaces in relation to bedding shows that the axial surface direction of conjugates coincide when related bedding values are rotated to coincidence (fig. 4, A). This is consistent with the rotation of early D2 structures by D3, explaining the variation of D2 axial surface directions. Similarly the line of intersection of the axial surface of actual D2 conjugate folds (representing the intermediate principal stress direction during D2) are coincident for all sets irrespective of external bedding orientation (fig. 4, B). This shows that D2 and D3 intermediate principal stress directions were coincident. This coincidence of D2 and D3 structures cannot be explained by superposition of the D2 conjugate sets on an earlier fold (the major fold geometry), because it is not possible to generate the conjugate sets on both the steeply dipping section of structure (the northern side of Mt Bischoff) and the shallowly dipping section with a suitable oriented stress field. In addition, cleavage overprinting of the D2 folds has been observed (fig. 1, D), and that cleavage is axial plane to D3 folds.

*Third(?) generation structures*

Probably third generation mesoscopic structures are illustrated in Figure 1, F-H. They are variable in form, as upright flexural slip folds, symmetrical kink bands and single trains of S or Z folds which are probably flexural-slip drag-fold. A moderate cleavage has been developed which overprints pre-existing structures and is consistent in orientation (fig. 5, A). D3 folding produced the overall fold geometry of Mt Bischoff shown in Figure 6, along with two measured profile sections. The overall antiformal nature of the structure near the summit of Mt Bischoff is undoubted (c.f. Groves and Solomon, 1964), but the steep south-facing, southerly-dipping sections shown on their cross sections is not confirmed by this study. In particular the southernmost dips shown by Groves and Solomon (1964) are northerly and this study suggests that the enveloping surface of the southern limb of the structure is dipping shallowly north. It is proposed that the overall fold is an antiformal flexure, because the associated cleavage is steeply dipping, but this conclusion can only be proved if drilling data were available in the southernmost area of exposure. The exposed southern section of Mt Bischoff probably represents a broad antiformal crest containing several broad M-folds (see block diagram, fig. 6). Reference to Figure 6 also shows the geometry of the northernmost D3 fold crest, which has a hinge trace of 230°. The statistical fold hinge direction derived from plots of bedding poles from both the eastern and western cross-sections (figs. 5, B, C) trends to 268° and 266° respectively. Consequently the D3 event was also imposed on a shallowly dipping surface and anisotropy caused by several active fabric elements during D3 produced this discrepancy between fold axis and hinge trace orientations.

*Fourth(?) generation structures*

In the open-cut areas, sporadically in the western area and abundantly in the eastern area, a well developed cleavage trending 010° to 025° is associated with upright flexural slip folds with a half wavelength of about 0.5 m. The fold event is also shown in Figure 5, B which shows a weaker girdle cutting the N-S girdle indicating a fold trending at about 10° to 035°. This spread is consistent with the broad spread in Figure 5, C. In thin section the age relationship between the easterly trending cleavage and the NNE trending cleavage is ambiguous, as both form grain boundary trends and tend to share pressure shadows. Both surfaces have not been studied in a single specimen of phyllite. The form of the spread of bedding, and the consistency of the E-W structures suggests that the NNE trending event is later. There does not appear to be any macroscopic structure related to the NNE trending mesoscopic folds.

## AGE OF FOLDING IN THE PRECAMBRIAN ROCKS

No large-scale recumbent folding has been reported in Tasmania in rocks younger than the Eocambrian/Cambrian sequences, and this observation also applies to the Cambrian(?) sequences overlying the Bischoff Series of rocks. Consequently it is inferred that the recumbent folds (D1) are Precambrian in age. Groves (1971) reports that the maximum principal stress directions in Mt Bischoff D2 folds differs from that in the earliest folds in the Cambrian rocks, and this is supported by the current study (Explanatory Notes for 1:50 000 geological map in prep.). It is thus inferred that Mt Bischoff series D2 folds are also Precambrian in age.

However, the major antiformal flexure of Mt Bischoff is co-axial with folds in the Cambrian sequence of the Waratah River and also with folds in Cambrian spilite and argillite/greywacke sequences to the north (Explanatory Notes for 1:50 000 geological map in prep.). Consequently it is postulated that the Mt Bischoff fold represents a major closure of a fold event which also affected the Cambrian rocks and thus is probably Devonian in age. These are inferred to be the earliest Devonian folds in the area (Seymour, 1980).

The NNE trending folds are compatible in both style and orientation with folds of the West Coast Range/Valentines Peak trend, which occur at Mt Pearse and are also present as minor folds in the overlying Cambrian rocks. It is proposed that these folds are of the same age and therefore Devonian.

## CONCLUSIONS

The history of deformation of the Mt Bischoff series of rocks, as proposed here, differs substantially from all previous structural interpretations. The inferred antiformal nature of the major D3 folding, and the inferred recumbent to reclined D1 event have previously been misinterpreted. In addition, the proposal that the E-W major fold was the earliest folding event (Groves and Solomon, 1964; Groves in Groves *et al.*, 1972) is shown to be incorrect. The complex geometry of fold hinge orientations is caused entirely by the development of conjugate folds on an anisotropic, overturned, dipping surface during D2, and subsequent rotation of those structures during D3. Unfortunately, the profile form of D1 folds cannot be ascertained at this stage, but it is suggested that major D1 folds may be present between the Waratah River section and Mt Bischoff summit section.

A summary of folding events is as follows:

- D1 produced isoclinal to very tight folds and a good axial surface slatey cleavage in suitable rock types. The major folds were recumbent to reclined;

- D2 produced asymmetric conjugate folds, using bedding and cleavage structures produced during D1 as active fabric elements. The asymmetry and anisotropy resulted in highly variable hinge line orientation but highly consistent axial surface intersection orientations. Only sporadic cleavage development occurred;

D3 compression resulted in the formation of the major antiformal flexure defining the Mt Bischoff structure, and also developed an excellent upright crenulation cleavage in suitable rock-types. An upright cleavage also developed in sandstone. Anisotropy, caused by the complexity of pre-existing structures, resulted in a large directional divergence between hinge traces and fold axis orientations. The D2 fold axis (intersection of related axial surfaces) and the D3 fold axis (statistical axis of bedding rotation) were parallel.

D4 produced minor folds trending NNE with an associated upright cleavage.

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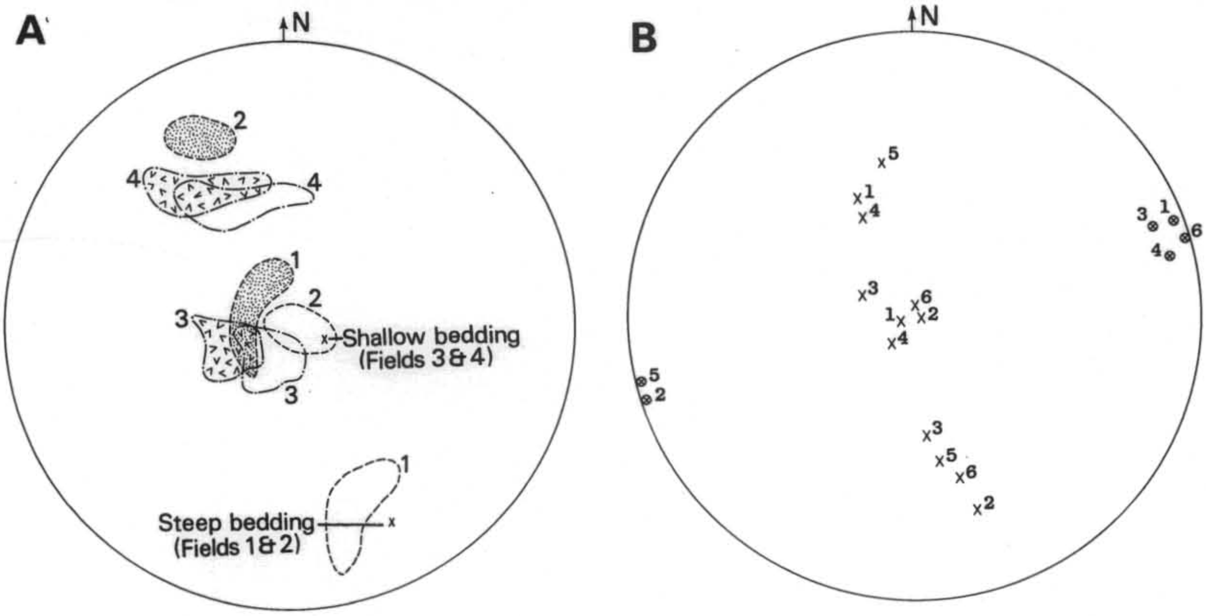


Figure 4. *A: Orientation of conjugate F2 axial surfaces in relation to bedding. Rotation of bedding values to coincidence (arbitrarily horizontal) results in the close juxtaposition of related folds (fields 1 & 2 related to steeply dipping beds coincide with fields 3 & 4 respectively on rotation).*
*B: Line of intersection of axial surfaces (⊕) related to axial surfaces (×) are coincident before rotation, showing co-axial nature of F2 and F3 folds.*

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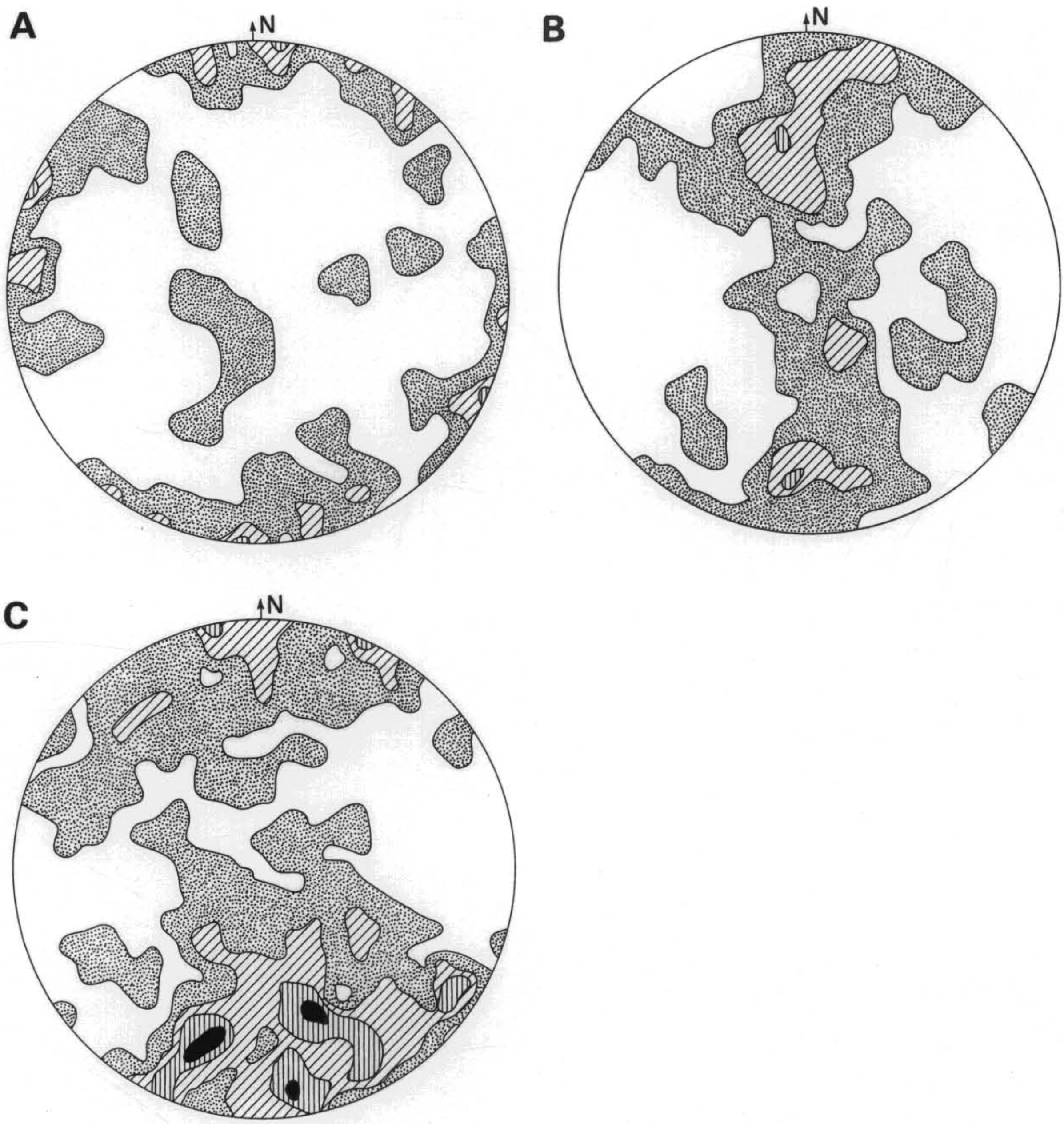


Figure 5. *A: Projection of poles to cleavage (Lower hemisphere) at Mt Bischoff. 55 values contoured at 1, 5, 9% per 1% area.*
*B: Projection of poles to bedding from east of Mt Bischoff summit (lower hemisphere). 79 values contoured at 0.6, 3.5, 7% per 1% area.*
*C: Projection of poles to bedding from west of Mt Bischoff summit (lower hemisphere). 143 values contoures at 0.35, 2, 3, 4.5% per 1% area.*



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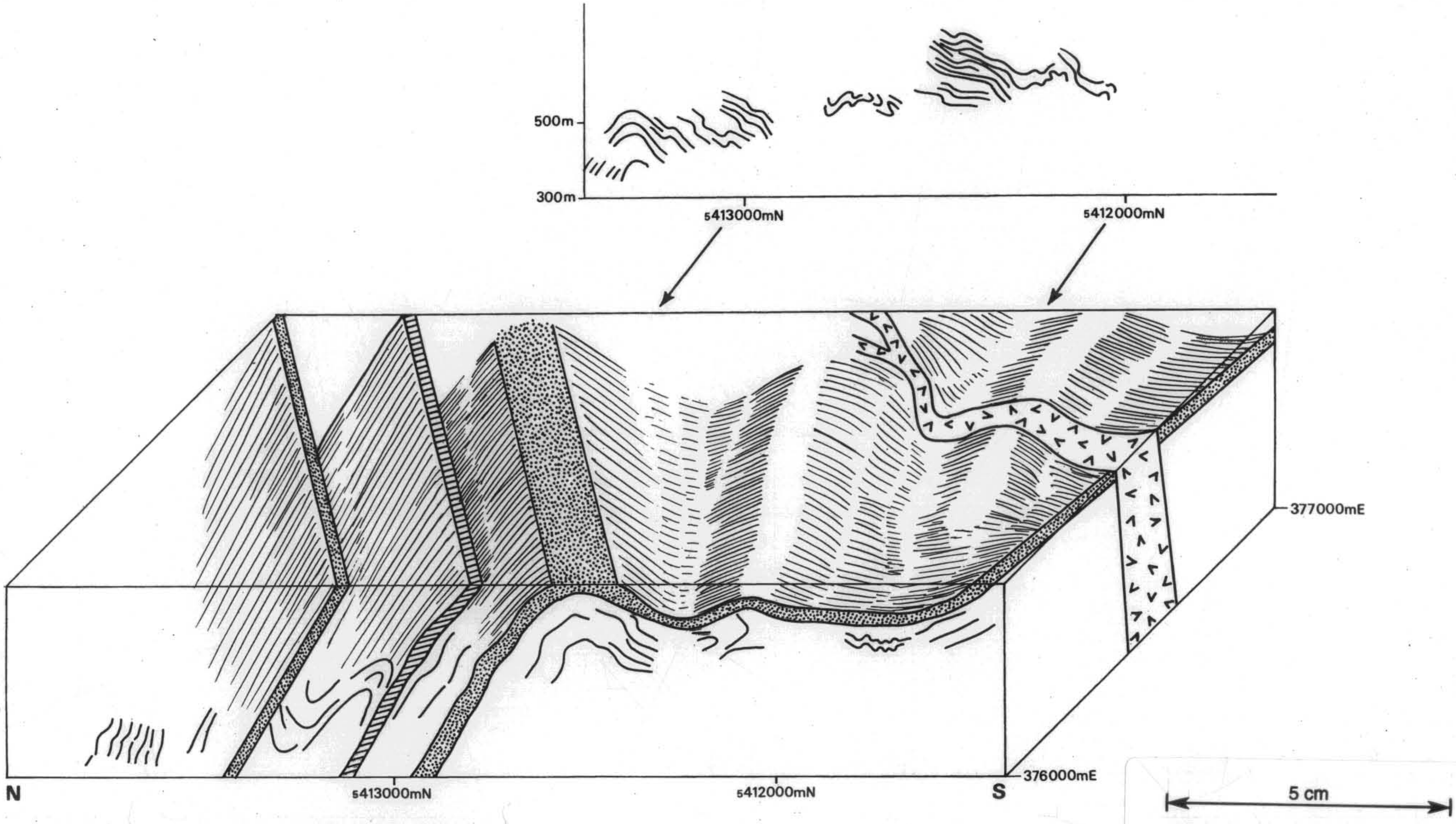


Figure 6. *Block diagram showing the geometry of F3 folds at Mt Bischoff. The structure is transected by a quartz-feldspar porphyry dyke.*