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THE TECTONIC HISTORY OF THE PALAEOZOIC SEDIMENTS OF THE MOSSMAN 1: 250,000 SHEET AREA NORTH QUEENSLAND

by

B.J. Amos

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SUMMARY

The structure of the Mossman Sheet area is dominated by steeply dipping beds and steeply plunging folds of varying magnitudes. The regional strike is north-north-west, and most of the beds dip more than 60°. About a third of the folds plunge more than 60°.

The earliest formed folds - termed the First Folds - were tight with steep limbs and sub-horizontal axes trending north-north-west. These established the regional strike. Subsequent folds - termed Second Folds - formed under a different stress system, were mostly broad and predominantly steeply plunging; the plunge of their axes was determined by the intersection of their axial planes and the steeply dipping limbs of the First Folds. The direction of plunge is variable.

Later deformation formed slaty cleavage throughout the area, accompanied by some cleavage folding (de Sitter, 1956) with steep plunges. This cleavage cuts incongruently across folds of earlier deformation periods. The formation of the cleavage varied according to the metamorphic conditions in the area. In the east of the area the deformation was plastic, and the rocks were uniformly cleaved; in the west of the area deformation was more brittle and the cleavage was concentrated in dominantly argillaceous sediments to form definite zones, which resembled shear zones.

Wrench faults of uncertain age displace the sediments in the west and north-west. Most of the major faults are parallel to the strike; they are later than the last folding and at least some of them are later than the last cleavage, but the displacement along the faults is uncertain.

The sediments were deposited in a basin, which trended north-north-west and whose western margin was the Precambrian Shield. The First Folds were the result of a horizontal compression normal to the margin of the basin. As the result of a strong compression farther south, sediments migrated laterally into an area of less stress and the steeply plunging Second Folds were formed. The vertical movement of sedimentary material at this stage was restricted, probably by the load of overlying rocks. Renewed lateral compression was not transmitted into folds because the sediments were already strongly folded, and as a result widespread slaty cleavage was superimposed on the previous folds.

INTRODUCTION

This report describes the structure and tectonic history of the Palaeozoic sediments in the Mossman Sheet area. It is a preliminary report based on field mapping completed during the 1960 field season; a final report will be compiled when mapping of the Palaeozoic sediments in the adjacent Cooktown Sheet area is completed in 1961.

The major structures were obtained from aerial photographs at scales of approximately 1:84,000 and 1:25,000. Supplementary field observations then gave information on the orientation of these structures, their structural style, the modes of their formation, and the relationships of one to another. These major structures are described in this report, but no detailed work was practicable in the time available. Consequently, the structures described here, and the tectonic history deduced from them, are simplifications of complex structures formed over a long period.

The structural sketch map (Plate 1) at the scale of 4 miles to 1 inch, is an uncontrolled compilation, based on aerial photographs at 1:84,000 scale.

PREVIOUS WORK

There are few references to the structure of the Mossman Sheet area. Many reports on mines in the area have recorded the attitude of the bedding and cleavage, but only five publications have described any regional structures.

Jack (1884) compiled a regional map of the Hodgkinson Goldfield, on which were marked the dip and strike of the beds, some of the lithologies, and the positions and orientations of the known gold-bearing reefs. Most of the quartz veins and dykes mapped by Jack were proved to be chert beds by the 1960 regional mapping.

Jensen (1923) briefly mentioned north-west or west-north-west folding in the Chillagoe and Hodgkinson Formations, and he also referred to a "crush conglomerate in a wide belt of slates" at the Mitchell River Bridge.

Bryan (1925) described the strata trending north-north-west at Mount Holmes and north-north-west and north-north-east at Mount Carbine, as extremely metamorphosed. The Chillagoe Series were reported by Bryan to strike north-west and west-north-west, and conformably underlie the Hodgkinson Formation; and he quoted Jensen's observation that both the Chillagoe and the Hodgkinson beds were folded to the same extent on the same axes at the same time. Bryan also mentioned that the strata in the Hodgkinson and Palmer districts had a north-west strike and a steep dip to the north-east, and they were uniformly folded with no intense plication or appreciable metamorphism.

In 1939, A.G.G.S.N.A. published a report on the Hodgkinson district, in which it was stated that the beds strike mainly 315° and 337° and dip to the north-east at high angles. In the central zones of the district the bedding strike was reported to be east and the dip vertical, and this was explained as being caused by a thrust associated with the intrusion of the "Hanns Tableland Granite" (Mareeba Granite - Morgan (1961)). Folding in the area was ascribed to the granite intrusion at Dimbulah, Mareeba, and Molloy. This area was covered by Jack's 1884 map.

In 1940 A.G.G.S.N.A. published a Report of the geology along the Palmer River. East of Maytown the report described a large anticlinal formation with a cleaved conglomerate near its axis. The axis of the anticline corresponded approximately to the axis of a fold, which contains a cleaved conglomerate immediately east of the Cannibal Creek Granite, and the axis of another fold north-north-west of the first, near the Palmer River, and separated from the first by a fault.

Early descriptions of the Hodgkinson area mentioned replacement quartz zones or silicified shear zones, which trend closely parallel to the dip and strike, but cut across it in places. The zones are described as ranging from 3 feet to 40 feet wide, laminated parallel to their margins, mappable for about 20 miles, and forming prominent physiographical features. In 1960 regional mapping of this area has shown that these silicified zones are radiolarian cherts. Most of them are thinly bedded, but some are recrystallised and in places resemble vein quartz or silicified material. The chert bands are competent, and have in many places along their margins formed a locus for faulting.

This has formed long faults along the contacts of the chert bands, with the less competent rocks on the other side of the fault plane having divergent dips and strikes. As a result the chert bands resemble a quartz zone crossing the strike.

STRUCTURE

The tectonic history of the Palaeozoic sediments in the Mossman Sheet area was complex, with several periods of folding and cleavage formation, resulting in a diversity of fold structures. The early folds are now mainly obscured by the later folds, but they have controlled the orientation of the later structures and they form the regional trend of the rocks in this area.

The structure is dominated by steeply dipping bedding and steeply plunging folds of all magnitudes. The regional strike is north-north-west, and most of the bedding planes dip more than 60°; overturned beds are fairly common. Most of the fold axes plunge more than 40°, and the remainder plunge more than 60°; almost all the major folds plunge at 60° or more.

In the following account the first or earliest folds are referred to as the First Folds, and the period during which they were formed as the First-Fold Period. Subsequent folds, superimposed on the first folds, will be referred to as Second Folds, irrespective of their age relationships with one another, as these at present are too obscure to be distinguished or subdivided.

In the west and south of the area, most of the rocks are not greatly deformed. Sandstones and greywackes are generally uncleaved, and slightly folded. Sedimentary structures are well preserved in the arenaceous sediments. The intervening shales are generally cleaved, but in places they are only fissile parallel to the bedding planes of the arenite interbeds, apparently due to sedimentation and compaction.

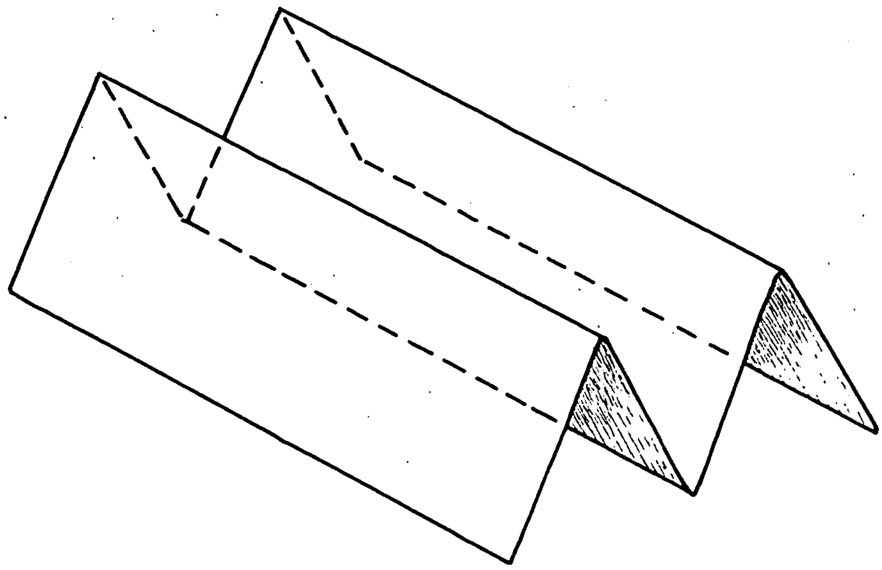
The chert is a competent rock and is not greatly deformed. Widespread incompetent disharmonic folding within the thinly bedded chert may be a slump formed when the chert was still plastic, but coherent. The thin beds are rarely disrupted during this slumping, though the folds are complex, in many places recumbent, and several feet in amplitude. Some of these folds are difficult to distinguish from minor tectonic folds, and consequently small folds in the chert are unreliable for structural analysis.

In the east and north of the area deformation has been more plastic, and slaty cleavage has formed in both the shales and the arenites, and in the cherts.

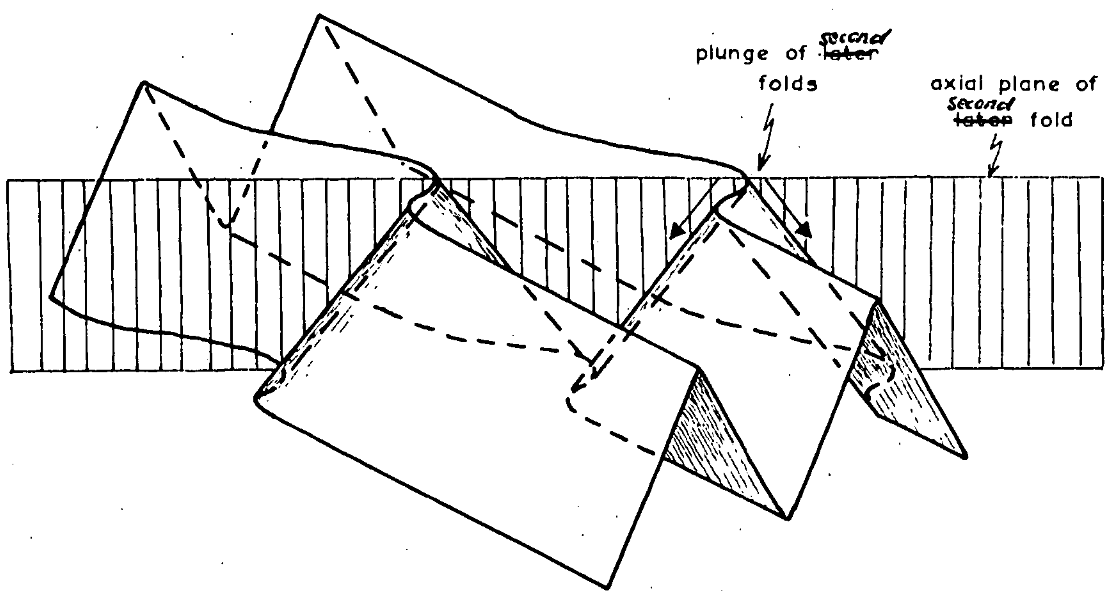
FIRST FOLDS

The details of the First-Fold Period have been obscured by later deformation; the general form of the First Folds and their regional trend can be reconstructed from the folds still visible and from their effect on the orientation of the Second Folds. this makes more sense. D.D.

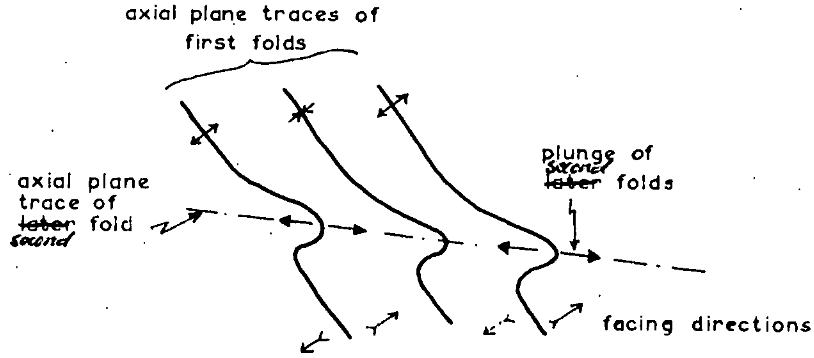
The First Folds are tight with sub-horizontal axes, steep or slightly overturned limbs, and narrow crests and troughs. These folds originally trended north-north-west, imparting a steep dip to the sediments and establishing the regional trend. Cleavage formed during folding was restricted to the axial zone of the folds; the folds appear to have been partly accordion folds, with most of the folding adjustments taken up by slip along the bedding planes in the limbs, and the folding at the hinges was accomplished by movements along cleavage.



a. Idealised first folds



b. First folds refolded by a later fold with a vertical axial plane



c. Diagrammatic plan view of b.

Fig. 1A Diagrammatic illustration of the relationship between first and ~~later~~ second folds

Fig. 1 Folds between Thornborough and Woodville

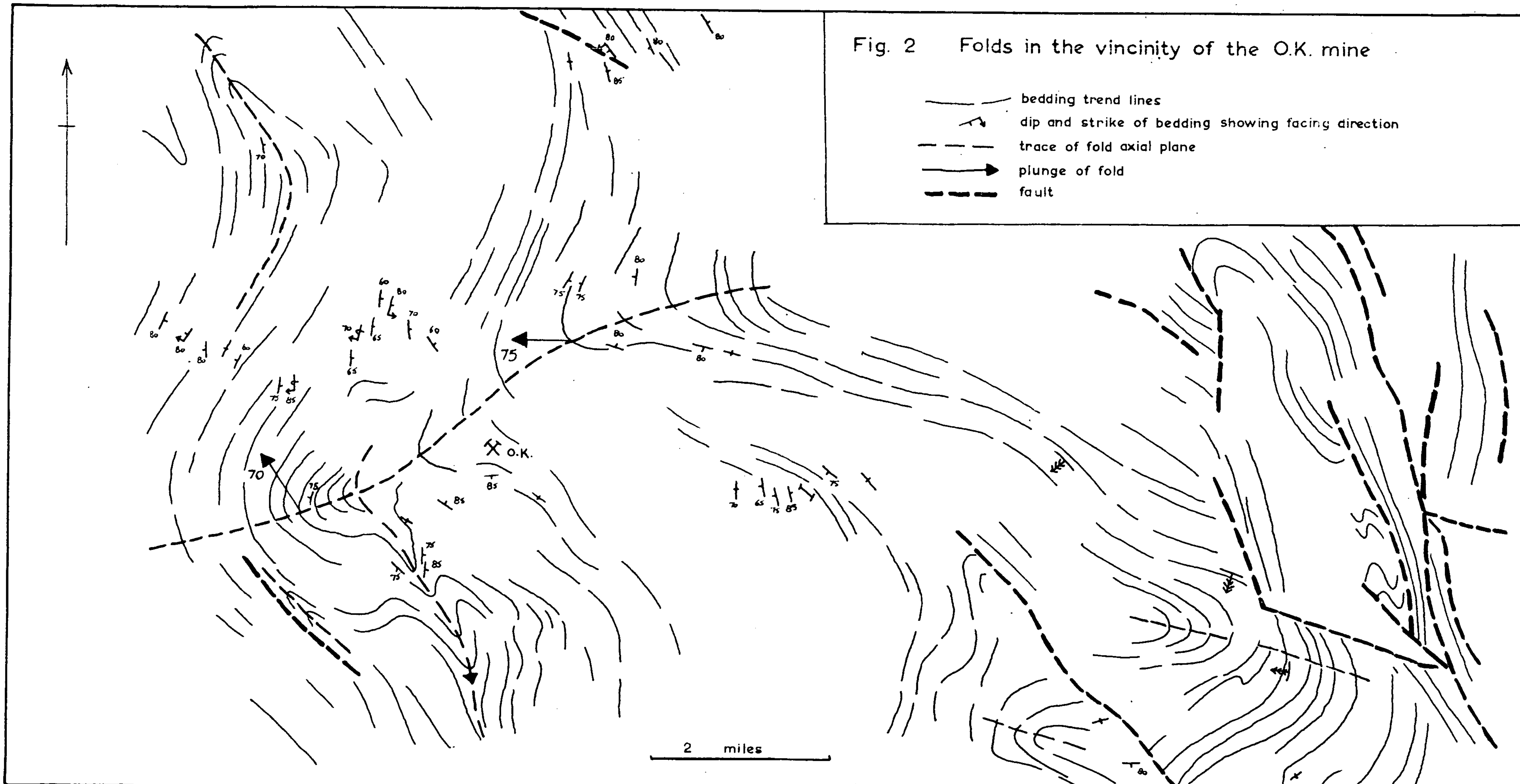


Fig. 2 Folds in the vicinity of the O.K. mine

The steeply plunging Second Folds were formed by folding superimposed on steeply dipping beds. As the axis of a fold must lie on the bedding planes, the Second Folds axes tend to plunge steeply, because they are confined to the steeply dipping beds of the First Folds (Figure 1A). Thus the steep bedding dips of the First Folds are preserved in the steep plunges of the Second Folds.

One of the First Folds, relatively undisturbed by later folding, is exposed 6 miles south-east of Mount Mulligan and $5\frac{1}{4}$ miles west of Thornborough (Figure 1). The axial plane of the fold strikes north-north-west and dips 75° to the east. The beds face towards the axis and indicate a syncline. The limbs of the fold dip 60° to 80°, and the east limb is overturned. Slaty cleavage, parallel to the axial plane of the fold, has disrupted and partially obscured the bedding in the crest of the fold; but many minor folds in the greywacke beds, still preserved in the axial zone, all plunge consistently at about 5° to the south-south-east and indicate the plunge of the major fold.

Other First Folds are described in the next section, together with the Second Folds that have refolded them. Most First Folds, however, have been reconstructed mainly by facing reversals in parallel striking beds, which would have otherwise been mapped as a continuous succession of strata.

SECOND FOLDS

All the Second Folds were superimposed on the steeply dipping limbs of the First Folds; this resulted in most of the Second Folds having a steep plunge, parallel to the intersection of the axial plane of the new fold and the steeply dipping bedding planes (Figure 1A). At the same time the First Folds are distorted, with new angles and directions of plunge, and folded axial planes; the orientations of these structures depend on the attitude of the Second Folds and the degree of later folding.

Therefore the plunge of the Second Folds will depend upon the orientation of the axial plane of the new fold, and the dip of the bedding in the First Fold. The inclination and direction of the plunge may be reversed, but it will always lie in the axial plane.

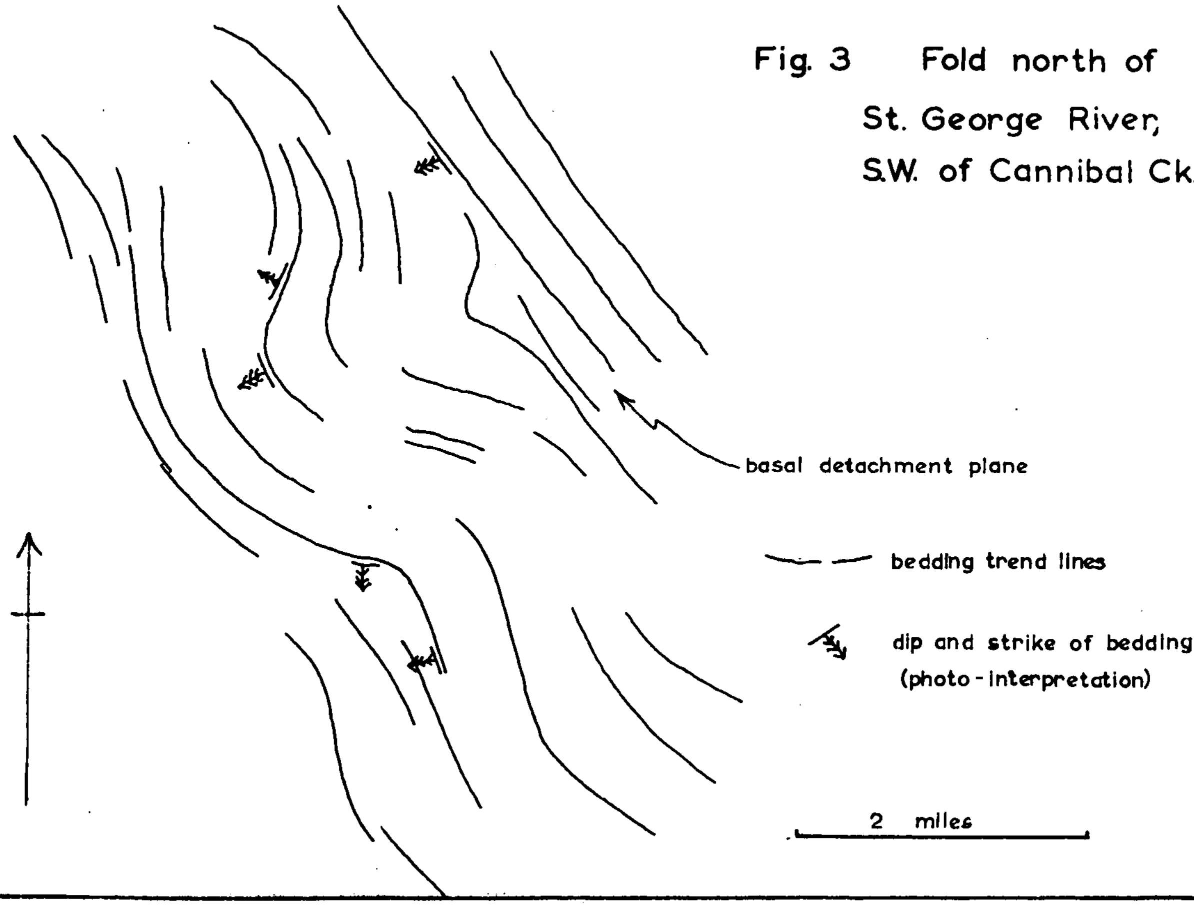
An example of a Second Fold, which plunges in different directions along the trace of the axial plane, is exposed north and west of the O.K. mine (Figure 2). Here a fold trending north-east refolds an earlier fold which has an axial plane roughly parallel to the regional strike. The plunge of the younger fold at one place is 70° to the north-west, and four miles farther north-east along the axial plane it plunges 75° to the west.

The structural sketch map (Plate 1) shows the trend lines of the bedding, and hence the surface outlines of the folds. In the east of the Sheet area the axial planes of the Second Folds are nearly all oriented north, though they may not be all of one generation; westward Second Folds are more open than in the east, and their axial planes trend more nearly north-east, or in some places north-west.

Thornborough fold.

An example of a First Fold refolded by steeply plunging folds is exposed in the Thornborough area (Figure 1). It occurs in a fault block that extends north-west from near Thornborough to Woodville, east of Mount Mulligan. In the northern part of this block there are many late folds, 1 to 2 miles wide, with steep axial planes that strike north-north-east. The folds plunge steeply; in the area where they were examined -

Fig. 3 Fold north of St. George River, S.W. of Cannibal Ck.



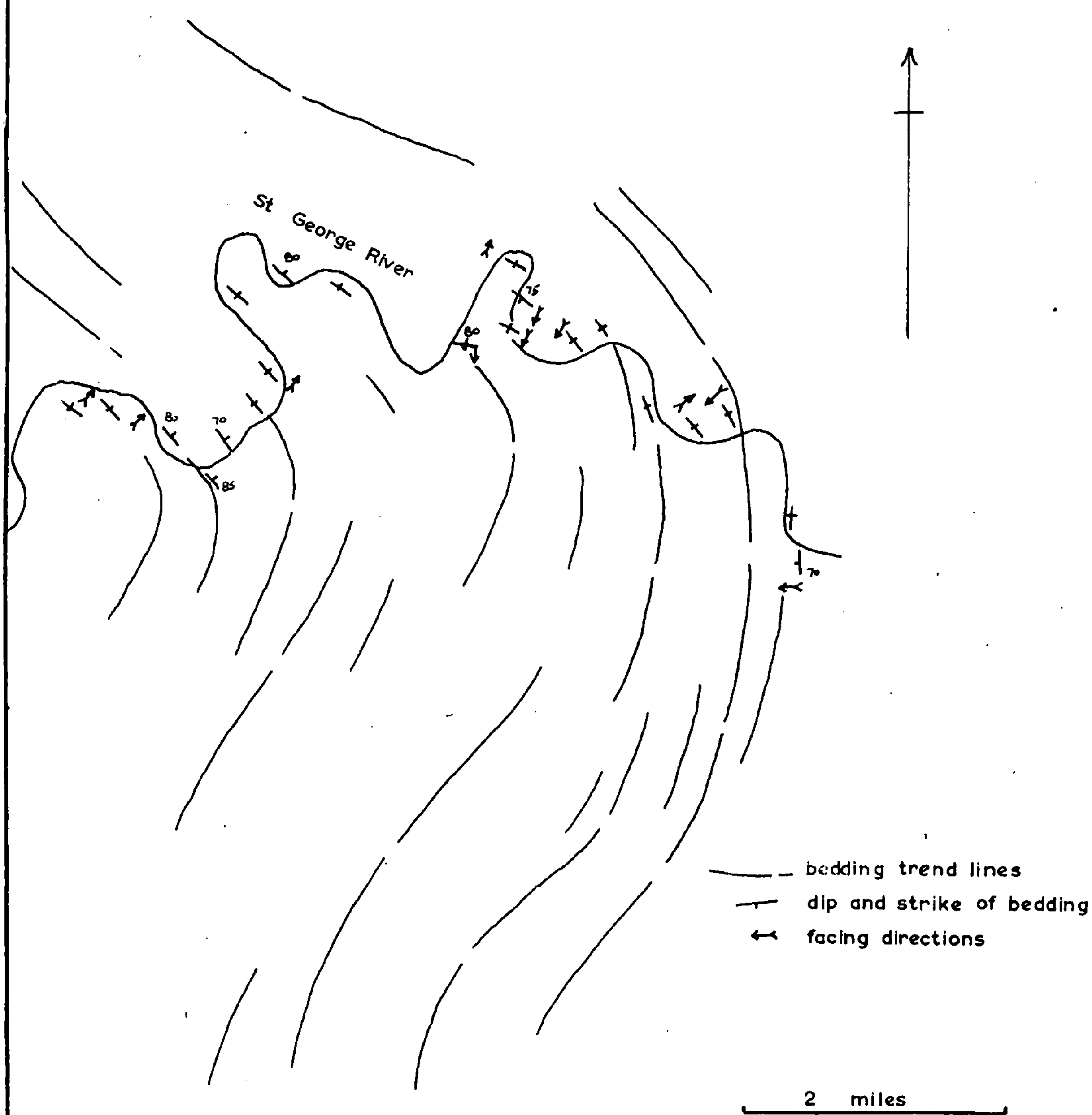


Fig. 4 Fold on St. George River, above its confluence with the Mitchell River

the plunge was 75°to the east-south-east. Traverses across the limbs of these folds showed several facing reversals and the crests of small folds about 200 yards wide, corresponding to these facing reversals, are visible on the aerial photographs within the limbs of the large folds. The axial planes of these small folds can be mapped around the noses of the steeply pluhging Second Folds, parallel to the bedding and folded with it.

The large north-north-east folds are confined to the northern part of the fault block, and southward the bedding maintains a uniform south-south-east strike for 3 miles with dips of 70° to 90°, in some places overturned. Within this section of regularly striking beds, there is, at one place, the visible crest and trough of a First Fold with its axial plane striking parallel to the bedding and a low plunge to the south-south-east. Southward the crest of this fold is not visible, but it can be mapped as a zone of facing reversals for at least 3 miles into another area of Second Folds, whose axial planes strike approximately north-north-west. It can also be mapped northward to where it connects with the folds refolded by the large north-north-east folds previously described.

The north-north-west fold occupies the southern part of the fault block, between Thornborough and Kingsborough. It is a broad monoclinal flexure plunging about 70° north-north-east in the area in which the plunge was measured. The fold is associated with a slaty cleavage that dips 70° east-north-east, roughly parallel to the axial plane of the fold. Some of this cleavage is exposed northward in the north-north-east folds, cutting across them incongruently, suggesting that the north-north-west fold is younger than the north-north-east folds.

FACING-REVERSALS

In the Thornborough folds there is evidence of a First Fold being refolded by two periods of Second Folding. They also provide an example in which the crests and troughs of the First Folds cannot be seen, but the folds can be detected and mapped as facing-reversals in a regular succession of beds with the same strike. These facing-reversals are common, and in many places they are the only indication of the First Folds. There are many explanations for the obscurity of the crests and troughs of the First Folds. The most likely one appears to be that the First Folds have been fairly tightly compressed, and have narrow crests and troughs; and because the plunge is shallow, the crests and troughs do not show up as a distinctive change in strike. The axial zones of the folds have been weakened by a pronounced slaty cleavage formed during folding, and this has tended to disrupt and obscure the bedding across the crests and troughs of the folds. This effect was probably intensified by adjustments during later folding.

An example of facing-reversals revealing First Folds within a Second Fold is the broad concentric fold on the St. George River just above its confluence with the Mitchell River (Figure 4). The St.George River flows along the axial plane of this fold for about six miles. The strata exposed in the river bed are mostly vertical, but a few beds dip at 70° to 80° to the east and west. Along this section there are three major facing-reversals unrelated to any visible folding or change in strike. Proceeding from west to east along the axial plane the beds face east for about three miles, then west for more than a mile, then east for about three-quarters of a mile, and finally west for about three-quarters of a mile. These facing reversals indicate two major anticlines separated by a major syncline of the First Folds.

The broad open fold with the east trending central limb, on the Mitchell River north of Mount Mulligan also shows opposed facing-directions, but their extent is not known (Figure 5).

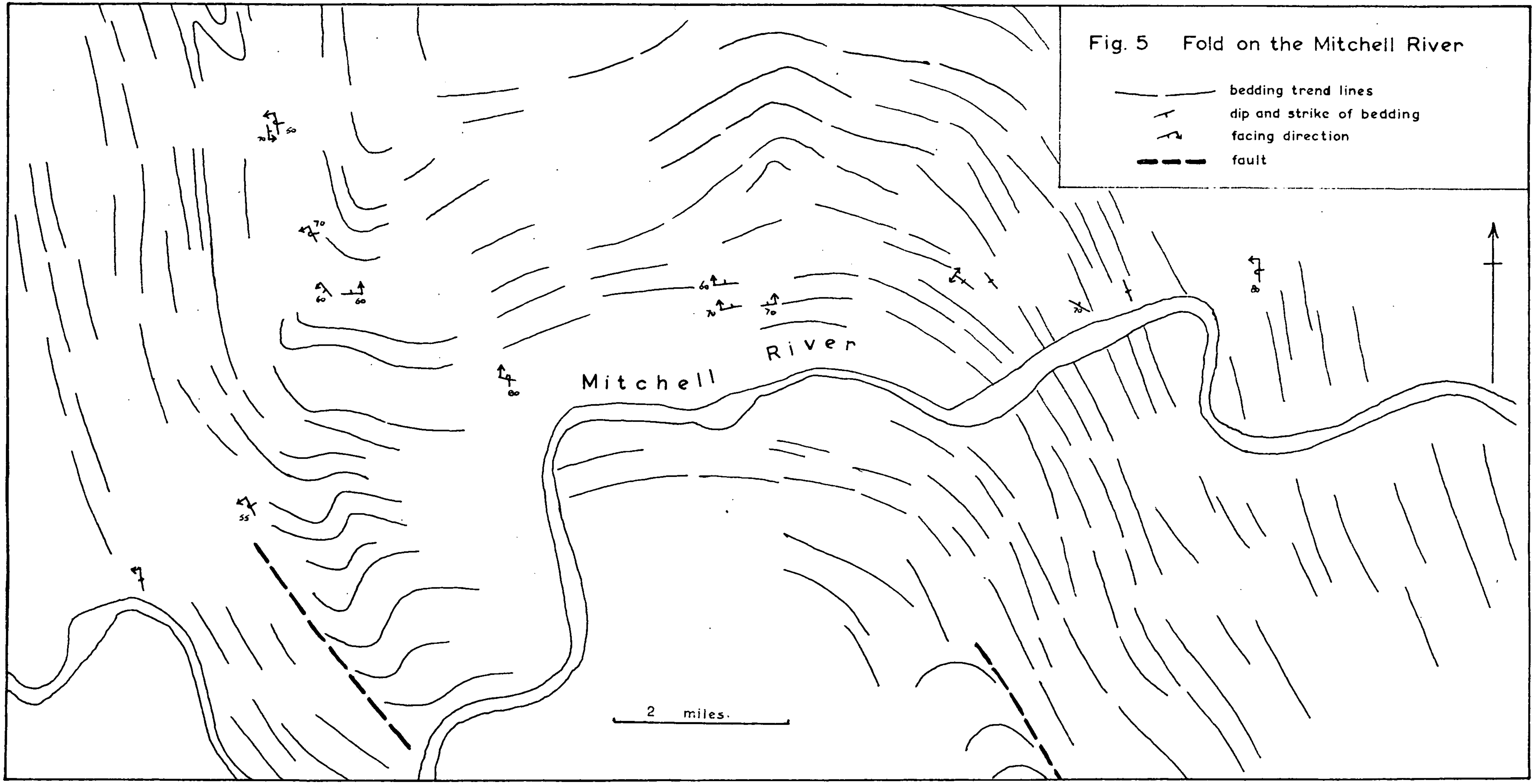


Fig. 5 Fold on the Mitchell River

MECHANICS OF FOLDING

Most of the Second Folds are a combination of concentric slip and cleavage folding, but in some folds one or other of these modes of deformation is dominant.

(i) Concentric folding

A small fold in the west of the area, 10 miles south-west of the Cannibal Creek Granites is a good example of predominant concentric slip folding (Figure 3). The basal detachment plane is visible on the aerial photographs; to the north-east of this plane (that is below it) there has been no folding, but to the south-west (that is above it) the beds are arched in a concentric fold, narrow, and pinched just above the detachment plane, but becoming broader farther away from it as the radius of curvature increases.

Probably the large open fold on the St. George River already described (Figure 4) is also due largely to concentric slip folding. Slaty cleavage related to the formation of either of these folds has not been observed; movement along concentric slip planes within and parallel to the bedding planes must have mainly formed the fold.

(ii) Cleavage folding

A fold in which cleavage has been the dominant mechanism in folding is a tight, almost isoclinal fold on the east margin of the Cannibal Creek Granite. This fold is associated with a pronounced axial plane slaty cleavage dipping 70° to the east-north-east, all the beds, including a moderately thick conglomerate, are cleaved. At the horizon of the conglomerate the fold plunges 60° to the north. The deformation of the conglomerate shows several structures typical of cleavage folds and it will be described in more detail.

The conglomerate consists mainly of fine-grained quartzite pebbles and a few of granite and sericitic arenite pebbles. The matrix is generally a medium-grained sandstone, but in places it is fine-grained, and pelitic. The pebbles are numerous, randomly scattered, but isolated from each other within the matrix; the cleavage visible in the matrix does not pass into the pebbles.

The pebbles are deformed to triaxial ellipsoids, with their long axes parallel to the lineation in the cleavage planes, which is parallel to the intersection of the bedding and cleavage, and hence to the fold axis. The long and intermediate axes of the pebbles lie in the plane of the cleavage. Many of the pebbles are lineated parallel to their long axes. The small pebbles have been more deformed than the large ones; some of the large pebbles are not greatly deformed. The sericitic, less competent pebbles have been deformed more than the competent siliceous pebbles. The ratios of the axes of the quartzose pebbles range up to $3:1:\frac{1}{4}$. The maximum pebble length is about 18 inches; most of the pebbles have major axes not exceeding 8 inches long.

Many of the pebbles are fractured. The fracture planes are inclined at about 45° to the major and minor axes of the pebble and generally parallel to the intermediate axis. Generally the fracture planes are slightly curved about an axis parallel to the intermediate axis; they do not normally pass completely through the pebbles; where they do, the pebble has commonly been pulled apart. Displacement along these fractures has, in most pebbles, further elongated the major axis of the pebble. Most of the pebbles have one set of fractures, but in some there are two sets. Similar fractures in elongated pebbles are described by Flinn (1956) in a conglomerate at Fettar. He described

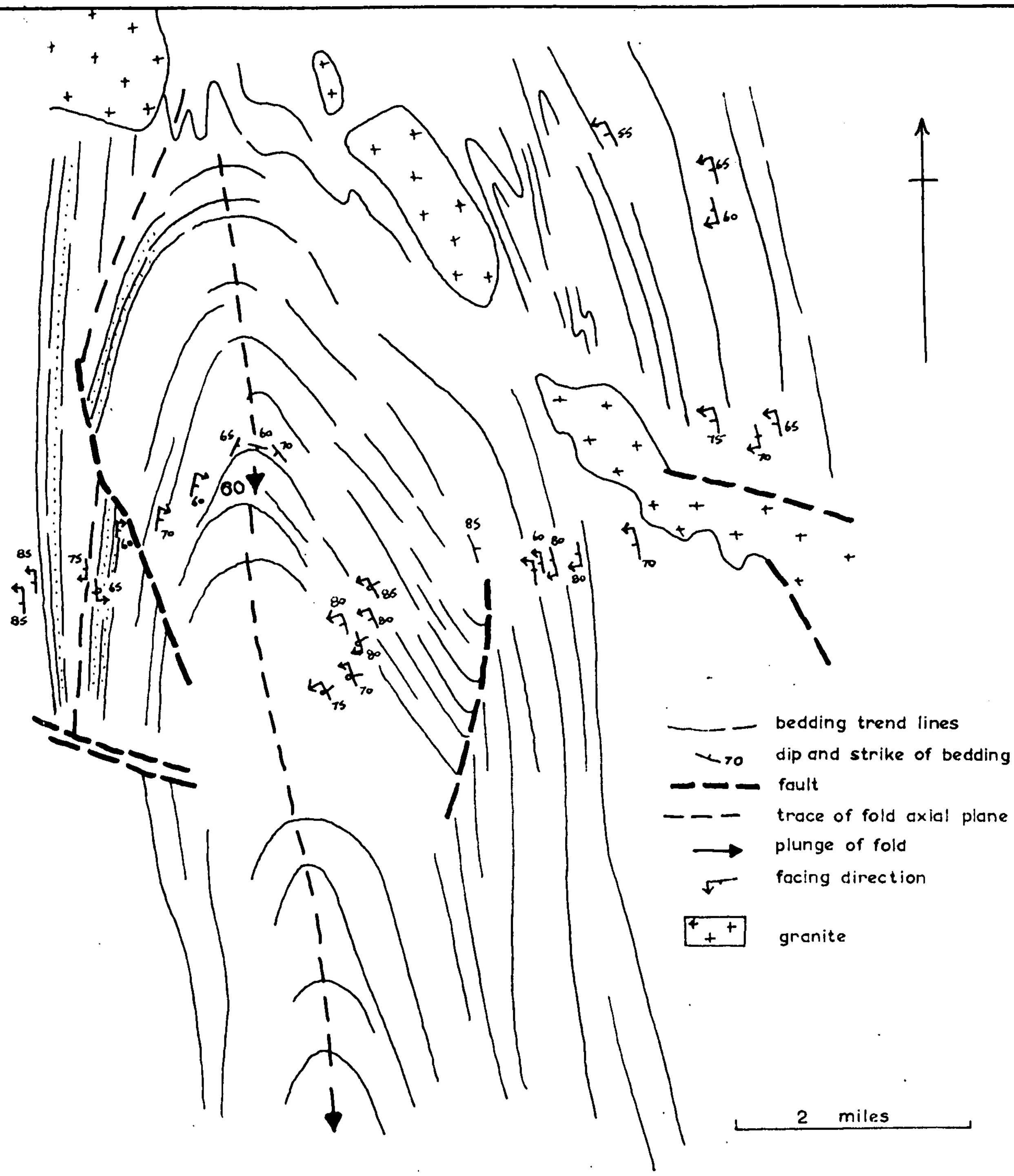


Fig. 6 Fold on the headwaters of the St. George River

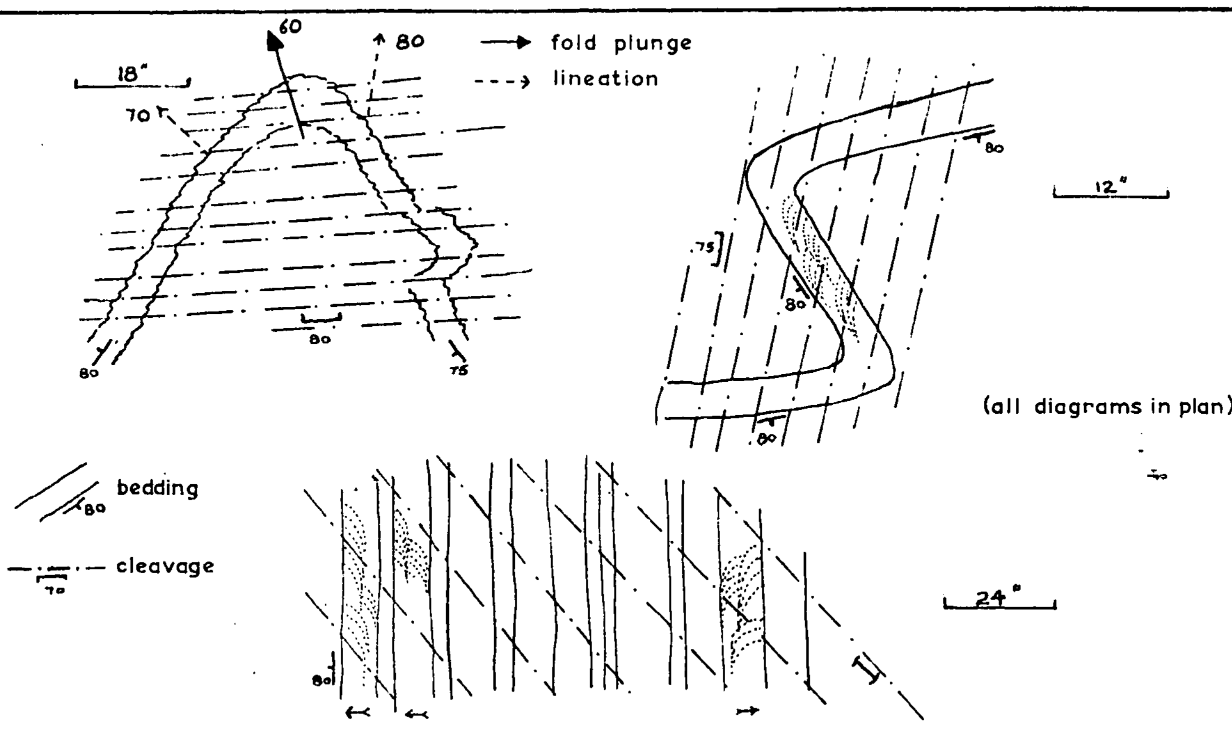


Fig. 7 Cleavage cutting incongruently across pre-existing structures

the fractures as representing ruptural deformation by pure shear, and suggested that the change from flow to shear deformation may be due to accelerated deformation or to a lowering of temperature or pressure.

A cleavage fold is suggested to explain these structures in the conglomerate because of the uniform development of cleavage throughout the fold, together with the pervasive deformation affecting even the competent inclusions in the conglomerates, and which have formed a penetrative lineation. Compression in c, normal to the cleavage planes, has been coupled with extension in b parallel to the fold axis, forming deformed pebbles with their major axes parallel to b, and tectonic transport parallel to a and normal to the fold axis. The fracturing of the pebbles is the effect of the continuing, or renewal of the same stress system under differing metamorphic conditions, forming brittle shear rather than flow.

(iii) Combined flexure and cleavage folds

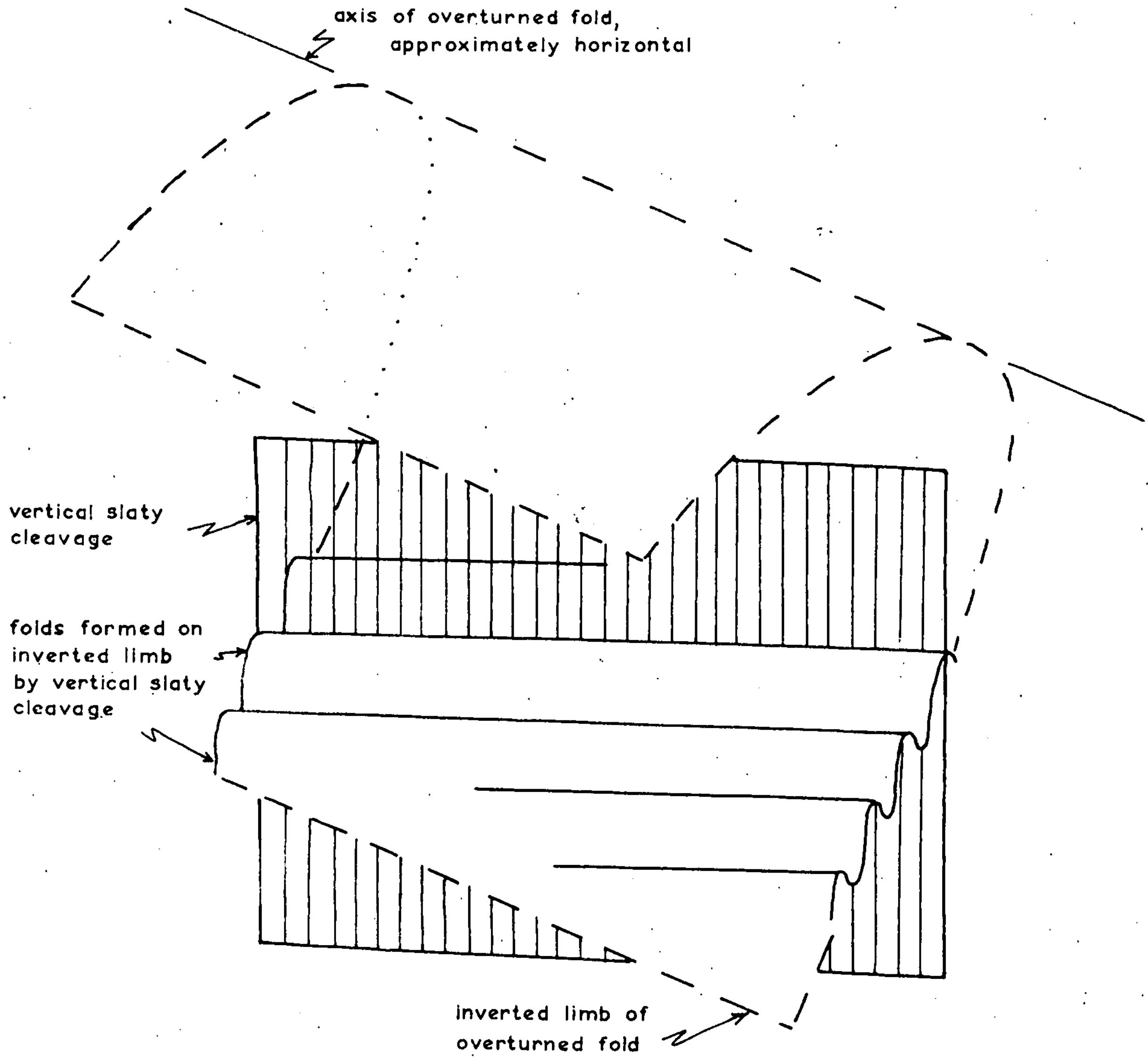
The large fold immediately south of the granites on the headwaters of the St. George River, shows the effect of both cleavage folding and flexural slip (Figure 6). The form of the fold is not that of concentric folding; the strata are thickened in the trough of the fold, more than can be accounted for as apparent thickening due to changing angle of dip, and the fold continues along the axial plane without any change in amplitude. Slaty cleavage is exposed in the pelitic beds but it is not exposed in the thick massive greywacke, which is widespread in this fold. Considerable bedding plane slip has taken place at certain horizons, as not all the beds in the trough of the syncline continue into the neighbouring attenuated anticline.

STABILISING EFFECT OF THE SHIELD

In the north-west and south-west of the area, near the contact between the Palaeozoic sediments and the Precambrian Shield, the Second Folds are only broad shallow flexures, and the strike of the beds is closely parallel to the edge of the shield. The dips of the Palaeozoic sediments are steep or overturned. The folds exposed here are probably First Folds, with steep dips and north-north-west strike, parallel to the edge of the shield; the shield has had a stabilising effect and has largely restricted or prevented any tight folding during the Second-Fold movements. In contrast, there has been considerable folding during the Second Fold Period, in the area immediately south of the Mitchell River. This folding may be due to a greater thickness of sediments in this locality; that is, the basement may here be more deeply buried than elsewhere.

CLEAVAGE

Most of this section deals with the slaty cleavage formed at a late stage in the deformation history of the area, during or after the last period of folding. Earlier cleavages were formed with the First Folds and some with the Second Folds, but with the exception of the cleavage in the axial zones of the First Folds, they are not pronounced, and have been further obscured by later deformation. They have been observed at scattered localities, and it has not always been possible to relate them definitely to any major structure. Consequently, they are not significant at present in deciphering the structure and they will not be described.



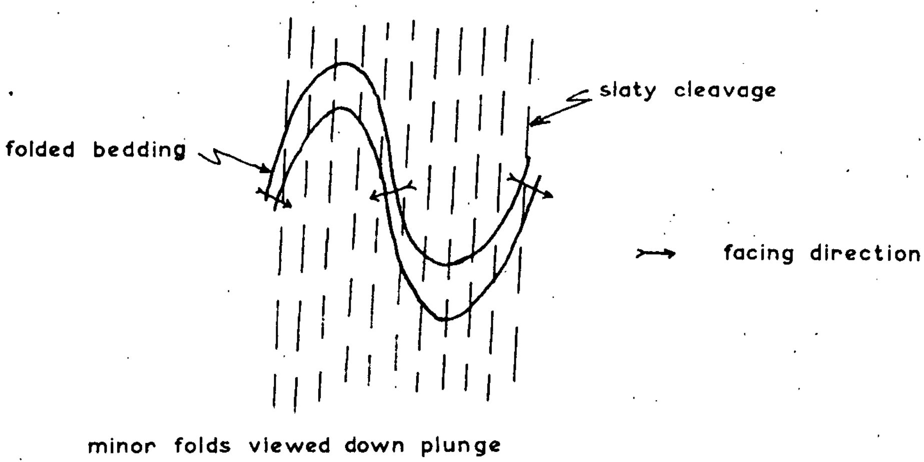


Fig. 7A Inverted folds at Noah's Head. (diagrammatic)

After the Second Folding, slaty cleavage was formed. This slaty cleavage trends north-north-west with a steep or vertical dip and it is found throughout most of the Sheet area; it is widespread in the east and north, but it is more localised and patchy in the west and south. In most places it is not demonstrably connected with any strong folding, but some large folds in the northern and eastern parts of the area may have formed at this time; for example, the monoclinal fold at Thornborough and the tight fold east of the Cannibal Creek Granite, are both associated with a steep north-north-west axial plane slaty cleavage.

Late cleavage in the east of the Sheet area.

In the east and the north of the area, the cleavage was uniformly distributed in many sediments, including chert and greywacke; it cuts across most earlier structures incongruently, but it did not obliterate them. Many steeply plunging folds of the Second-Fold Period are exposed and transgressed by the slaty cleavage making a large angle with the axial plane of the fold. In these folds the lineation, which are formed by the intersection of cleavage and bedding, plunge in different directions on the two limbs, neither direction corresponding to the plunge of the fold (Figure 7).

In other outcrops where the folds are not visible, the cleavage bears the same angular relationship to the bedding in closely adjacent parallel beds that face in opposite directions (Figure 7). This also indicates the superposition of the cleavage on an older fold.

In another place, on the coast 11 miles north of the Daintree River, at Noah's Head, a previously inverted bed, the lower limbs of an overturned fold, dipped about 50° to 60° to the west-north-west. Later the slaty cleavage was accompanied here by minor folding, forming minor folds about 6 feet wide in this inverted bed, with their axial planes parallel to the cleavage and their axes plunging about 35° to the north (Figure 7A). The resulting anticlines and synclines appear normal, but their sedimentary structures indicate that they are inverted. It must be emphasised that the folds have not been rotated; their unusual attitude is due to normal cleavage folding imposed on beds already inverted.

Late cleavage in the west of the Sheet area.

In the west and south the cleavage was not as uniform as in the east, probably due to differences in metamorphic conditions during its formation. Arenaceous and other competent sediments were resistant to cleavage formation, and the cleavage was concentrated in zones of dominantly argillaceous sediment, containing only thin intercalated beds of greywacke a few inches thick and rarely up to 2 feet thick.

In the early stages of cleavage formation in these argillaceous zones, the thin intercalated greywacke beds were folded and the shales were deformed by the cleavage; but as the deformation continued, differential slip began and was concentrated along particular cleavage planes and the shear so formed broke through the thin beds of greywacke (Figure 8). The greywacke beds were disrupted by this process and divided into short sections, or lenticles. As deformation continued, these lenticles were drawn apart and disoriented until the original stratification was obscured. These related structures are preserved at different localities.

Most of the disrupted fragments have a roughly triaxial ellipsoid form. Theoretically their long axes may be prolonged indefinitely along the intersection of the cleavage and the bedding, but in fact the long axis is usually only about 3 times the length of the intermediate axis. This is probably because when differential

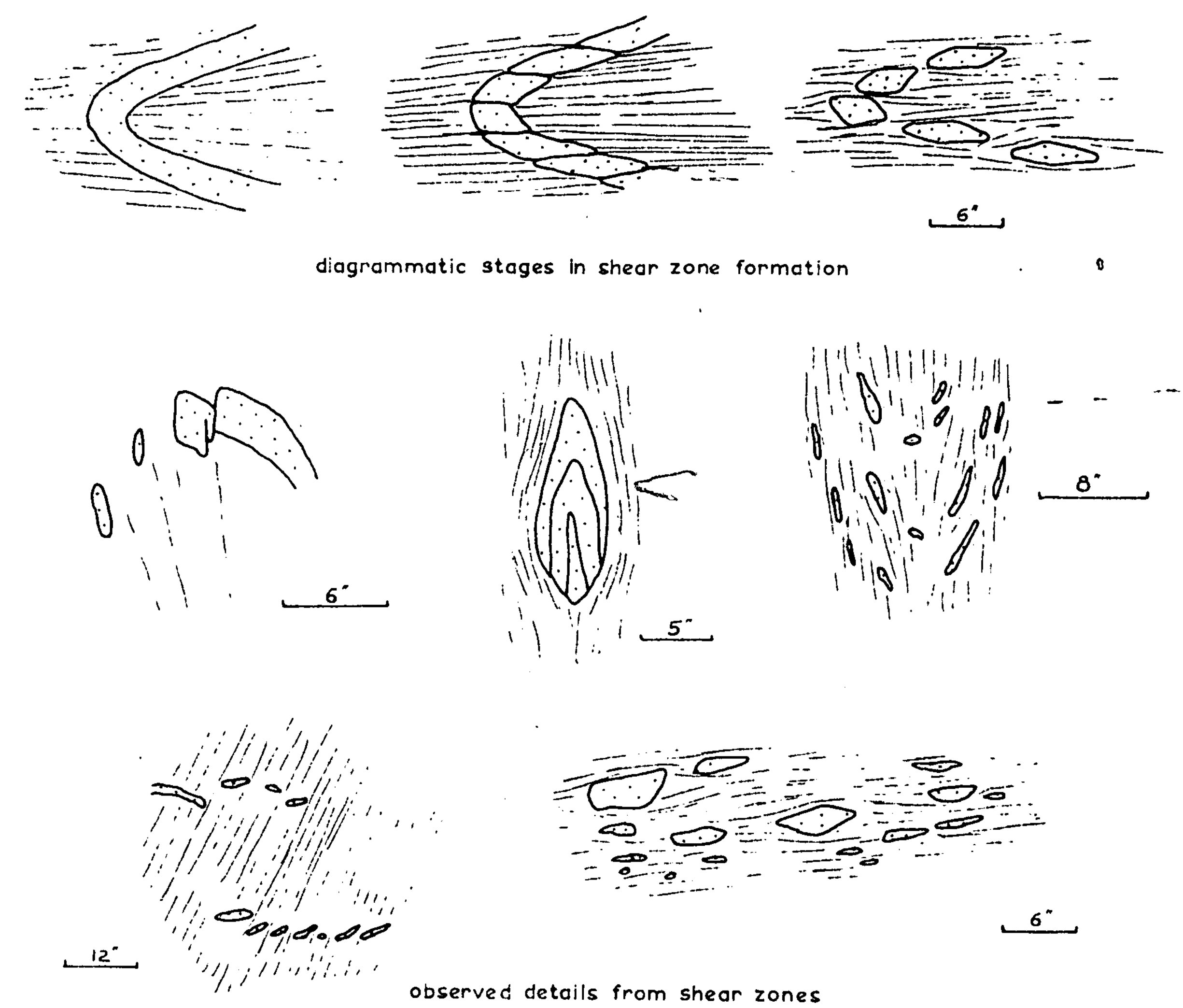


Fig. 8 Shear zones

greywacke
cleaved shale

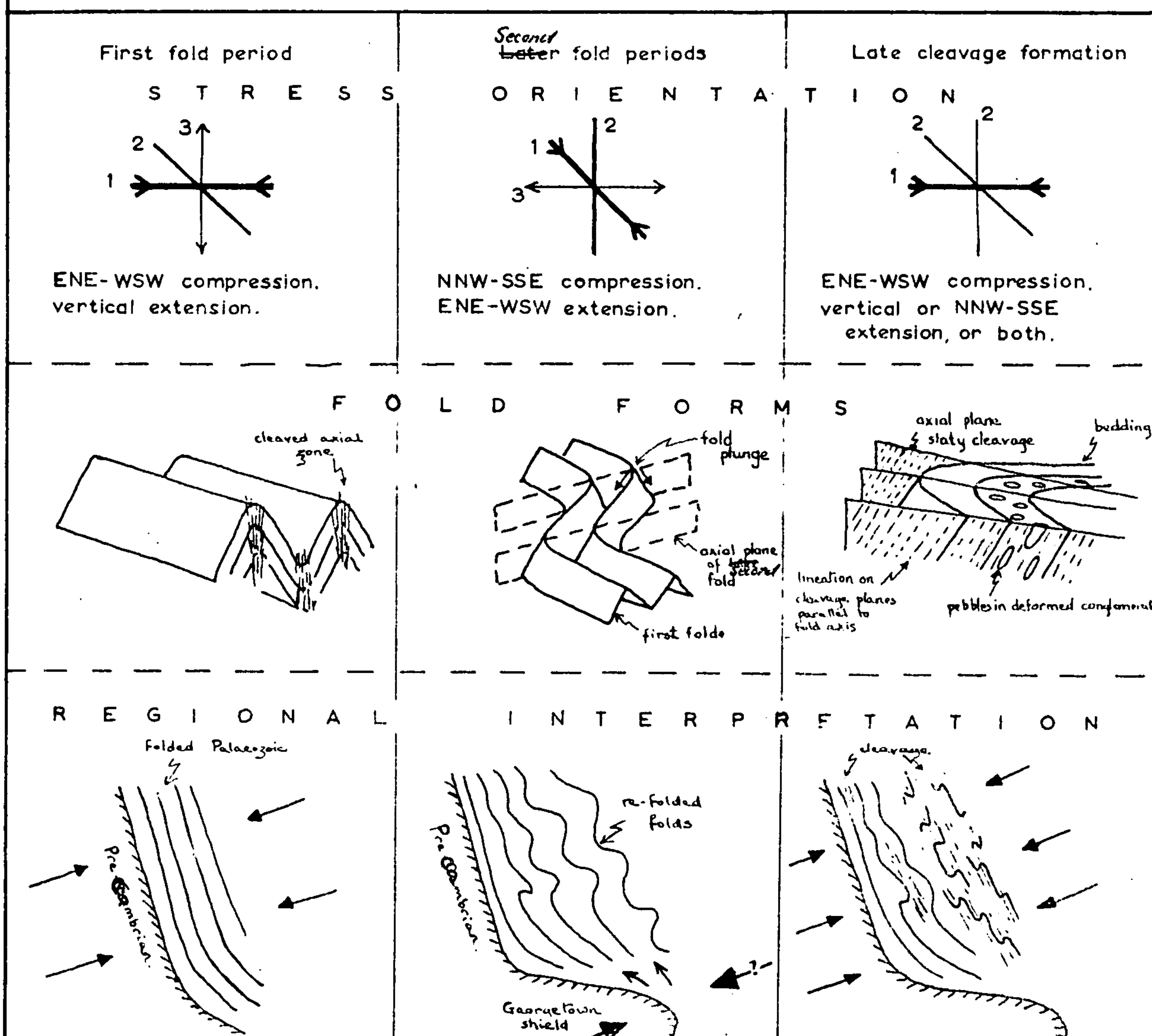


Fig. 9 Tectonic synthesis

movement transforms the cleavage planes to shear planes they are not plane surfaces, but are slightly curved, and do not preserve their individual identities for any great distance.

These zones of slaty cleavage, in which the cleavage has nearly obliterated the bedding, with concentrated differential movement along some or all of the cleavage planes, will be referred to as shear zones. This is not meant to imply that there has been any significant movement of one margin of the shear zone relative to the other, but that planes within the shear zone have moved slightly. Adjacent shear planes have moved in opposite directions and probably the net displacement was zero.

In places the shear zones resemble thick deformed conglomerates, particularly where they contain scattered ellipsoidal fragments in a strongly cleaved matrix and show no signs of stratification. The fragments are generally from 1 inch to 6 inches wide and in places their diameter may range up to 2 feet. Except where the shear zones are bounded by thick competent horizons, such as chert or massive greywacke, they merge into strongly cleaved stratified sediments. The shear zones are commonly only a few yards wide, but at the Mitchell River Bridge there is a shear zone at least four miles wide (referred to by Jensen (1923) as "a crush conglomerate in a wide belt of slate".) This shear zone, however, is subdivided by bands of uncleaved poorly exposed chert 20 feet to 30 feet wide. It is the widest shear zone in the western half of the area.

The shear zones in the west of the Sheet area are few and scattered, but they are more widespread eastward. They are particularly wide and extensive in a belt about 10 miles wide and 40 miles long trending north-north-west from Mareeba through Mount Molloy and Mount Carbine, and farther north to the granite at Mount Windsor. In this belt the shear zones are broad and close together, with only a few beds unaffected; even the thick bands of thinly bedded chert are closely cleaved. This belt of shear zones seems to be transitional to the rocks farther east, where shear zones are not exposed and the rocks are uniformly cleaved.

In some places pronounced cleavage along the axial planes of the First Folds formed shear zones which closely resemble those zones formed during the period of later cleavage formation. The shear zones of the First Folds differ from those of the Second Period in being consistently narrow, because they are confined to the axial zone of the folds, and have been refolded with the bedding by the Second Folds; the size of the younger shear zones range greatly and generally trend north-north-west.

RELATIONSHIP TO GRANITE INTRUSION AND FOLDING

The Mareeba Granite was intruded along the Mareeba - Mt. Windsor belt of shear zones, which may have localised the intrusions. The shear zones are hornfelsed by the granites, which were therefore intruded after the formation of the shear zones. Between the granites of the Hanns Tableland and Bakers Blue Mountain, and also between the granites of Mt. Windsor and Mt. Spurgeon, the shear zones have been pushed aside into anomalous orientations by intrusion of the granites. Apart from this deformation, the intrusion of the granites has not greatly affected the structure of the surrounding sediments.

The uniform cleavage in the east of the Sheet area, and the shear zones in the west of the area are both later than, or contemporaneous with, the Second-Fold Period, since in the eastern area the cleavage cuts across many of the Second Folds incongruently, and in the western and the eastern areas the cleavage is unaffected by the folding.

They both strike north-north-west and dip steeply and they appear to grade into one another. Consequently, the cleavage and shear zones are probably contemporaneous, resulting from the same stress system and differing in style because of different metamorphic conditions.

FAULTS

Most of the major faults are related to a late phase of deformation, subsequent to the Second Period of folding and cleavage formation. A possible exception occurs 14 miles east-south-east of the O.K. mine, in a region of complex folds and faults, where some faults may have been folded subsequent to their formation. Most of the faults are straight or slightly curved. There is little evidence of the inclination of the fault plane, but their straightness suggests a steep or vertical dip.

Most of the faults in the centre and east of the area are sub-parallel to the strike of the beds, and as marker horizons are absent, the amount and direction of the displacement are not known. The faults disrupt and displace the steeply plunging folds of the Second-Fold Periods, and some of them transgress the late slaty cleavage. Mount Mulligan is a block of Triassic sandstone, which has been preserved by downfaulting. The Mount Mulligan faults have the same trend and resemble other major faults in the Mossman Sheet area and this suggests that the major faults also have a vertical throw.

The down faulting of the Mt. Mulligan block, however, may be due to rejuvenation of pre-existing faults in the post-Triassic or possibly post-Cretaceous, as there may be some Cretaceous sandstone overlying the Triassic which, under different conditions of stress, forms a different direction of movement along the fault planes.

Two complementary sets of oblique faults trend north-east and north-west in the north-west portion of the area, adjacent to the Precambrian Shield, where the Palaeozoic sediments have a north-north-west strike and a re relatively undisturbed by Second Folds. The north-west faults are dominant, and the displacement along these faults has a sinistral horizontal component. The displacement along the north-east faults has a dextral horizontal component. Therefore, they resemble a wrench fault system, related to an east-west compression and a north-south extension. These faults transgress the First Folds obliquely and they are later than the folding; the direction of the major compressional stress is apparently the same for both the folds and the wrench faults, but the direction of least stress is vertical for the folds and horizontal for the faults.

A large wrench fault, 8 miles south-east of the O.K. mine, trands north-west with a dextral displacement. This fault separates two steeply plunging folds (Figure 2), whose axial plane trends west-north-west. The fault can be mapped for 10 miles; at both extremities it merges into the bedding planes. This is the only destral north-west fault observed in the area.

The marginal fault between the Palaeozoic sediments and the adjacent Precambrian Shield is only slightly sinuous, with a general north-north-west trend. The straight trend of the fault plane for many miles suggests a steep dip. The fault throughout its length is situated close to the western margin of a thick bed of sericitic and feldspathic sandstone, which is the base of the Palaeozoic succession in this area. This sandstone is dissimilar to any other sediment in the succession, and probably lies close to the original margin of the depositional basin.

This suggests either the position of the fault is strongly controlled by the original depositional unconformity between the Palaeozoic sediments and the underlying Precambrian, or that it is an old Precambrian fault, which by continued movement formed the margin of the Palaeozoic depositional basin. There is evidence of movement along this fault in the Cretaceous or post-Cretaceous; the fault has displaced the horizontal Cretaceous sandstone west of the O.K. mine with a vertical upthrow on the eastern side of about 250 feet. There is no indication of any horizontal movement. North of Palmerville another outcrop of Cretaceous sandstone is faulted, and here also the eastern block has been moved upwards relative to the western block.

POST-CARBONIFEROUS FOLDING

Tuffaceous sediments were deposited after the Second-Fold Period and the development of slaty cleavage; they have a maximum thickness of 130 feet. The tuffaceous sediments have been gently folded and their dips range up to 30°; the folds are broad, open, and symmetrical and the axes of the folds plunge about 15° to the north-west. Small folds are absent.

TECTONIC SYNTHESIS

The structures described in this report are the result of deformation in response to variously oriented stress fields acting upon a mass of sediments. These sediments were deposited in an area flanked on the west by the Precambrian Shield, and extending linearly north-north-west and south-south-east beyond the margins of the Mossman Sheet area. The eastern boundary of this area of sedimentation is obscured by the South Pacific Ocean. This area will be referred to as a <u>basin</u> in this ~~in this~~ account; it probably corresponds to the Hodgkinson Trough of White (1961) and part of the Hodgkinson Basin (Tectonic Map of Australia, 1960).

The following reconstruction of events is hypothetical, based on the probable orientation of stresses during successive fold periods and on the changes of dimensions of the rock mass during folding.

The First Folds shortened the basin laterally, normal to the fold axes, and extended it vertically. During this movement, sediments moved upwards into the folds to accommodate the shortening. The Second Folds extended the first folded belt laterally along the earlier axis of shortening, and shortened it along the strike. The later cleavage formation has again reduced the sedimentary basin along the First Fold axis and normal to the cleavage planes. During the Second Fold Period the size of the basin was probably extended both vertically and laterally.

The First Folds, trending north-north-west, were the result of a horizontal compression east-north-east and west-south-west at right angles to the west margin of the basin. This compression formed tight folds with near-vertical axial planes, and probably associated with faults. These folds were parallel to the western margin of the basin. At this stage the easiest direction of relief was upwards rather than laterally, and as folding proceeded, the lateral shortening was accomplished by sediments moving vertically by folding and faulting.

After these movements, sediments was forced to migrate laterally into the area, probably from the south, by an uneven compression of the sediments. This lateral migration of sediment towards the First Fold axes formed the steeply plunging Second Folds. At the present day, scattered exposures of Precambrian in the Atherton 1:250.000 Sheet area to the south indicate that the Precambrian Shield projected farther east of the Shield's margin in the Mossman Sheet area. Whether this eastward projecting Precambrian block was already in existence during the Second Folding, or whether it was being formed at that time by uplift of the basement, this part of the Atherton Sheet area seems a probable area for the uneven compression forcing the sediments to migrate laterally. An uneven distribution of stress within the basin sediments would result if either lateral compression forced the sediments against the projecting block, or, more likely, a wedge of the basement in this area was being uplifted. In either possibility, vertical relief by an upward squeezing of sediment must have been restricted, probably by the load of overlying rocks formed during the First Fold Period. Possibly during this time lateral compression was decreased on the sediments in the Mossman Sheet area, facilitating a lateral movement of material into an area of less stress.

When the stresses were once more equalised, compression along the old east-north-east to west-south-west axis was renewed. It appears, however, that relief from this compression could not easily be obtained by folding, probably because the sediments were already strongly and repeatedly folded, and most of the strata were already vertical and aligned approximately normal to the compression. In these conditions, deformation of slaty cleavage resulted by the compression normal to the cleavage planes, and dilation within the cleavage planes probably both vertical and horizontal. More steeply plunging folds were formed at this time.

The north-east and north-west wrench faults in the north-east portion of the area may have been formed either at the close of the first period of compression when the First Folds were formed, or during the later period of renewal compression along the same axis. The north-west dextral wrench fault south-east of the O.K. mine implies a north-north-west compression and a horizontal east-north-east extension, and may therefore be related to the period of lateral migration into the area from the south. The major strike faults have been formed late in the tectonic history of the Sheet area.

During all these stages of deformation, stresses at any place may have been modified by the local conditions, resulting in a limited stress field of different orientation to the bulk stress field. Such modifications may be caused by the existence of local differences in lithology such as particularly competent or incompetent beds, uneven distribution of a lithological unit, the presence of a nearby stable block, different depths of burial, or the anisotropy of earlier structures. Consequently, individual structures have slightly different styles and orientations, though formed in response to the same major stress system.

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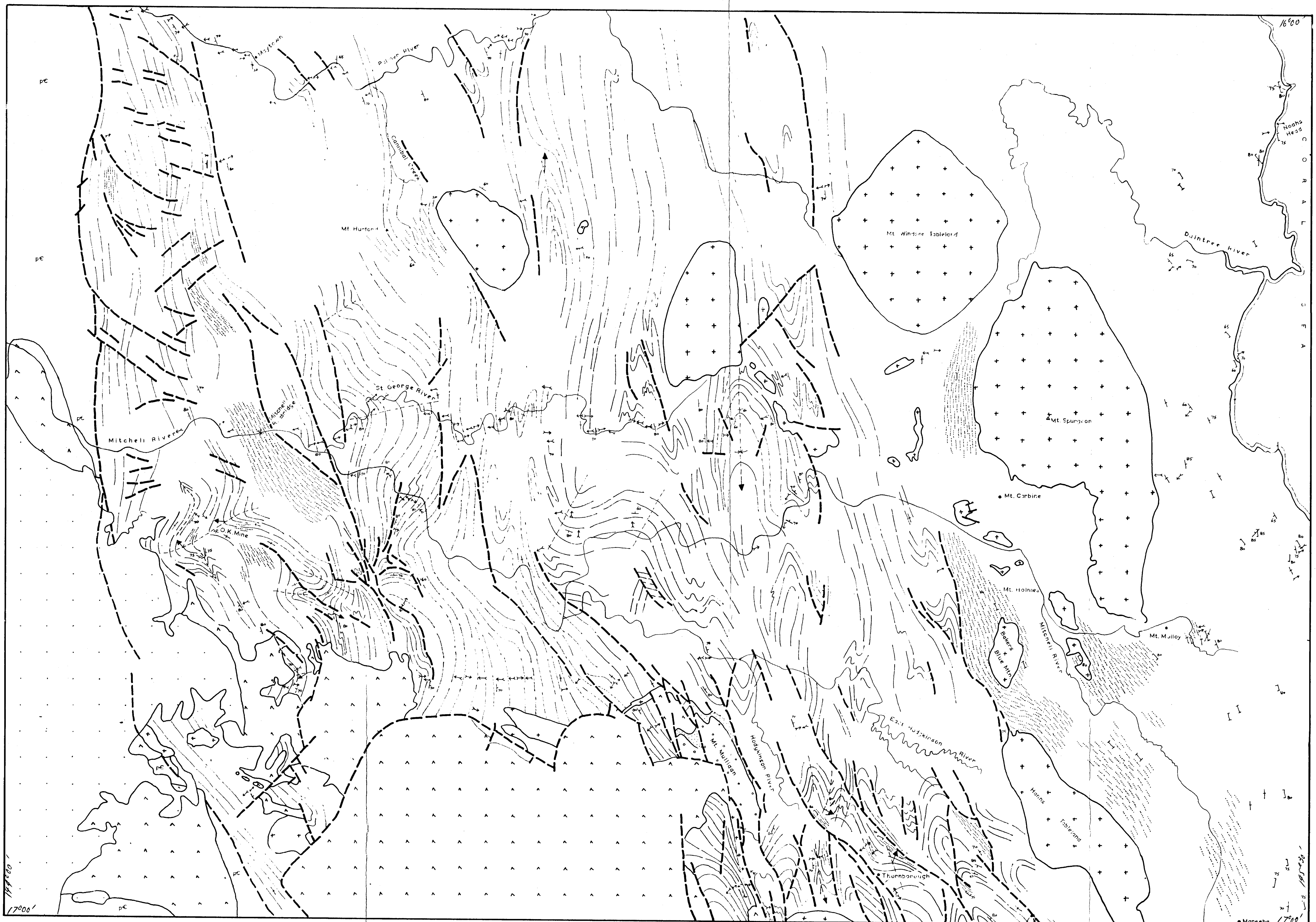

STRUCTURAL SKETCH MAP, MOSSMAN 4-MILE AREA