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POLYPHASE FOLDING IN PRECAMBRIAN, LOW-GRADE METAMORPHIC ROCKS, MIDDLE GORDON RIVER, SOUTHWESTERN TASMANIA

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(With one plate and three figures)

ABSTRACT

New exposures on the southern side of the proposed damsite on the middle stretches of the Gordon River reveal unequivocal examples of polyphase folding in the Precambrian, low-grade metamorphic rocks of southwestern Tasmania. Three groups of folds are deformed by kink bands. The first group comprises very tight, almost isoclinal, and recumbent folds with north-south trending hinges, and was formed by considerable subhorizontal overriding of the western block towards the east. These early, concentric folds are folded by more open, similar folds. The hinges of the second group of folds pitch shallowly north-northeastward on steeply dipping axial surfaces parallel to which there is a prominent transposition foliation developed in the phyllites. These folds were produced by a steeply inclined thrusting of the eastern block towards the west during low greenschist-facies conditions of metamorphism. Small-scale, similar-style puckers pitching steeply in the transposition foliation comprise the third group of folds, and were produced by subsequent subhorizontal movement in the phyllites of the eastern block southwards.

INTRODUCTION

The middle reaches of the Gordon River are deeply entrenched in regionally metamorphosed, Precambrian quartzites, phyllites and schists. A possible damsite on the Gordon River (fig. 1), immediately upstream from the confluence of the Gordon and Serpentine Rivers, is currently being investigated by the Hydro-Electric Commission of Tasmania. In the new road cuts and other excavations excellent exposures of complex folds can be separated into three main groups. Polyphase fold deformation of the Precambrian rocks in southwestern Tasmania has long been suspected by Spry (1957, 1962(a) and (b), 1963), Gee (1963) and several other workers, but until now no unequivocal examples of refolding have been described.

The rocks vary from massive quartzites through quartzose phyllites to chlorite schists, and there are some graphitic bands. The quartz layers vary in thickness from mms to tens of metres, and layers of phyllite appear to be even thicker. Phyllite comprises a little more of the total rock than quartzite.

The distribution and intensity of the folding appears to have been controlled by the quartzite, and none of the deformations is truly penetrative. Each successive deformation has tended to pick out the zones which were least affected by earlier deformations. The first group of folds, G_1, occurs in bands where locally the proportion of pelite to psammite is greatest. The second group of folds, G_2, is the most widespread and penetrative on the larger scales, but does not affect the thicker quartzite lenses on smaller scales (pl. 1, No. 2). The third group of folds, G_3, does not affect the thick quartzite bands, and is most intensely developed in the phyllite.

It must be emphasised that this paper is only a preliminary study, and that the data were collected from one hillside only, viz.: from half-a-mile along the ridge immediately south of the proposed damsite. The area is well suited for detailed structural analysis and it is to be hoped that this work is extended before the dam fills.

Group 1 Folds

The earliest recognizable group of folds, G_1, is composed of tight to isoclinal folds with north-south trending hinges and variably oriented, though commonly shallowly eastward or westward dipping axial surfaces (fig. 2*a*). The G_1 folds range in size from centimetres (pl. 1, No. 1) to tens of metres, and some may even be larger.

The folds in the quartzite layers have concentric, or modified concentric profiles, with geometries corresponding to folds *flattened less than 30% perpendicular to the axial surface. Some of the folds (fig. 3*b*) have bulbous, globular profiles and curviplanar axial surfaces. The sense of coupling of the longer limbs of the folds is congruous with the G_1 deformation having been caused by an apparently subhorizontal movement of the overlying rocks towards the east. There is no well-developed cleavage associated with G_1 folds, although it is possible that it was obliterated during later deformation.

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* *Flattening* (Ramsay, 1962, p. 312) was defined as a process of pure shear, and was measured (*ibid.*, p. 314) in terms of the variation of thickness in fold profile. An apparently flattened fold profile may, however, be the result of processes other than pure shear (e.g., simple shear), and thickness variations in one layer alone will not discriminate the mode of strain.

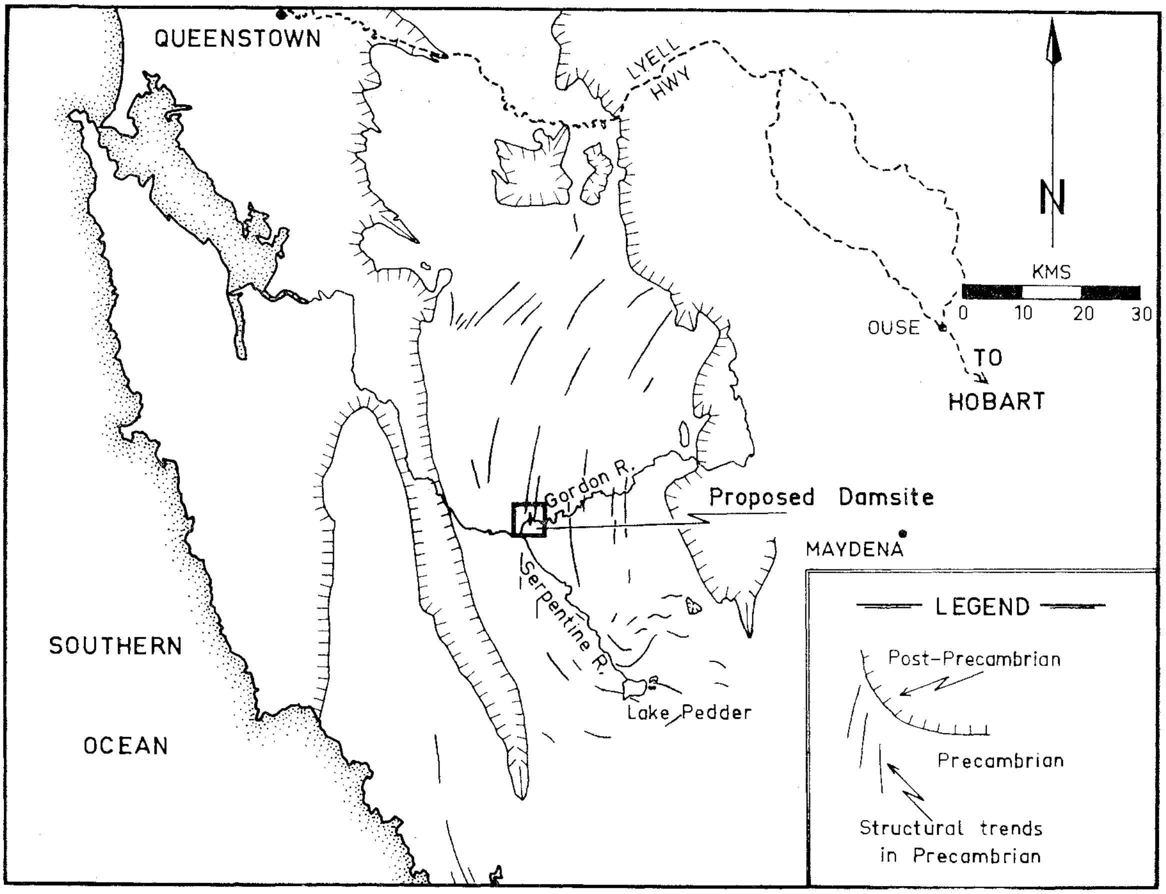

FIG. 1.—Structural location map of proposed damsite on Gordon River. (Modified from *J. geol. Soc. Aust.*, 9, Pt. 2, 1962.)

The variable orientations of the G_1 axial surfaces is attributed to rotation during the second phase of folding. Rotation of the folds about the G_2 axis to an arbitrary horizontal axial-plane position produces a strong north-south orientation of the G_1 hinges. Most of the G_1 folds were measured in two cuts along the road to the proposed powerhouse, and most of the G_2 folds from other outcrops to the south along the access road. Thus, in figure 2*b* the local axis of rotation of the G_1 folds has been used as the axis of unravelling rather than the statistical G_2 axis. However, although there is almost 20° divergence between this local axis and the statistical G_2 axis, almost the same distribution of G_1 hinges is obtained whichever axis is used in rotating the G_1 axial planes. The primary basis for distinguishing between G_1 and G_2 is whether refolding can be observed in outcrop, and peculiarities of style and orientation are subordinate criteria.

Group 2 Folds

The second group of folds has hinges which pitch shallowly north-northeastward on planar, steeply eastward-dipping axial surfaces. The profiles vary from open to tight, but are not isoclinal. G_2 folds are the most common and readily recognizable folds in the quartzite layers, and range in size from small puckers centimetres in wavelength (fig. 3*a*) to folds hundreds of metres across. The main anticlinorial structure of the damsite (Corbett, 1965) is a G_2 fold. In places the quartzite layers have been rolled up into large quartzitic rods, ten of metres across (fig. 2*e*), which in profile are more or less disconnected from each other giving the appearance of sigmoidal ‘tectonic fish’. A false impression of massive quartzite ridges parallel to the fold axis is produced where such rods cap topographic highs.

The G_2 folds in the quartzite layers have profiles of Class 1c (Ramsay, 1967, p. 366) which correspond to concentric folds flattened a little more than the G_1 profiles. The G_2 folds in the pelitic layers have profiles of Class 3 (*ibid*), so that the entire fold is propagated in the axial surface by alternations of profiles of Classes 1c and 3 producing a Class 2 (similar) fold.

The sense of coupling of the longer fold limbs together with the shallowly eastward-dipping

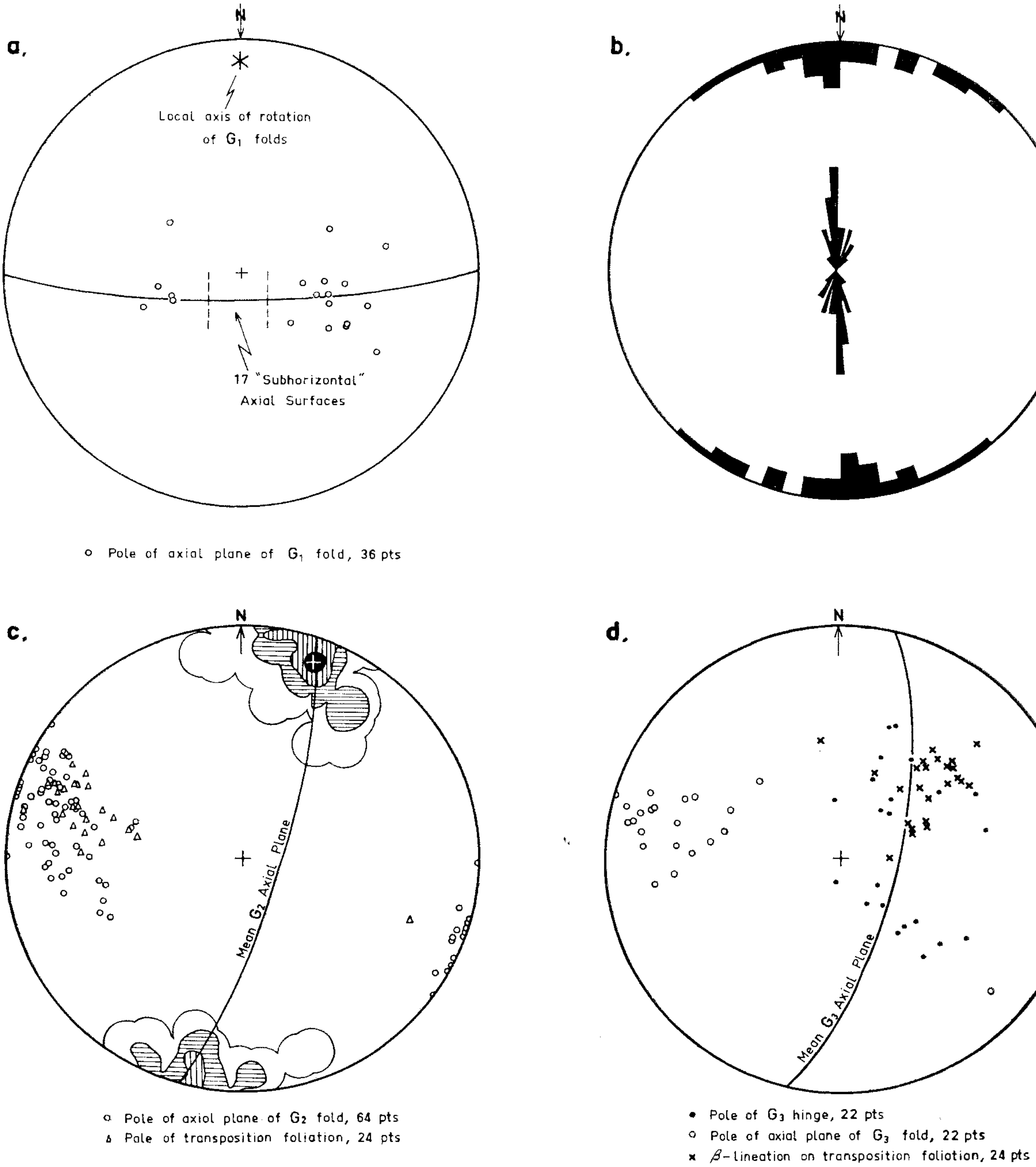

FIG. 2.—Structural elements of the three groups of folds. (*a*), (*c*) and (*d*) are Schmidt equal-area projections. (*a*) Poles of the G_1 axial planes. (*b*) Rose diagrams of 36 G_1 fold hinges after rotation of the G_1 axial planes to the horizontal about the local G_2 fold axis. (*c*) 64 G_2 fold hinges (contoured 1-5-10-15 points per 1% area) with a maximum plunging 12° at N20°. Poles of G_2 axial planes and transposition foliation are also shown. (*d*) Poles of G_3 hinges, axial planes and β-lineations on the transposition foliation.

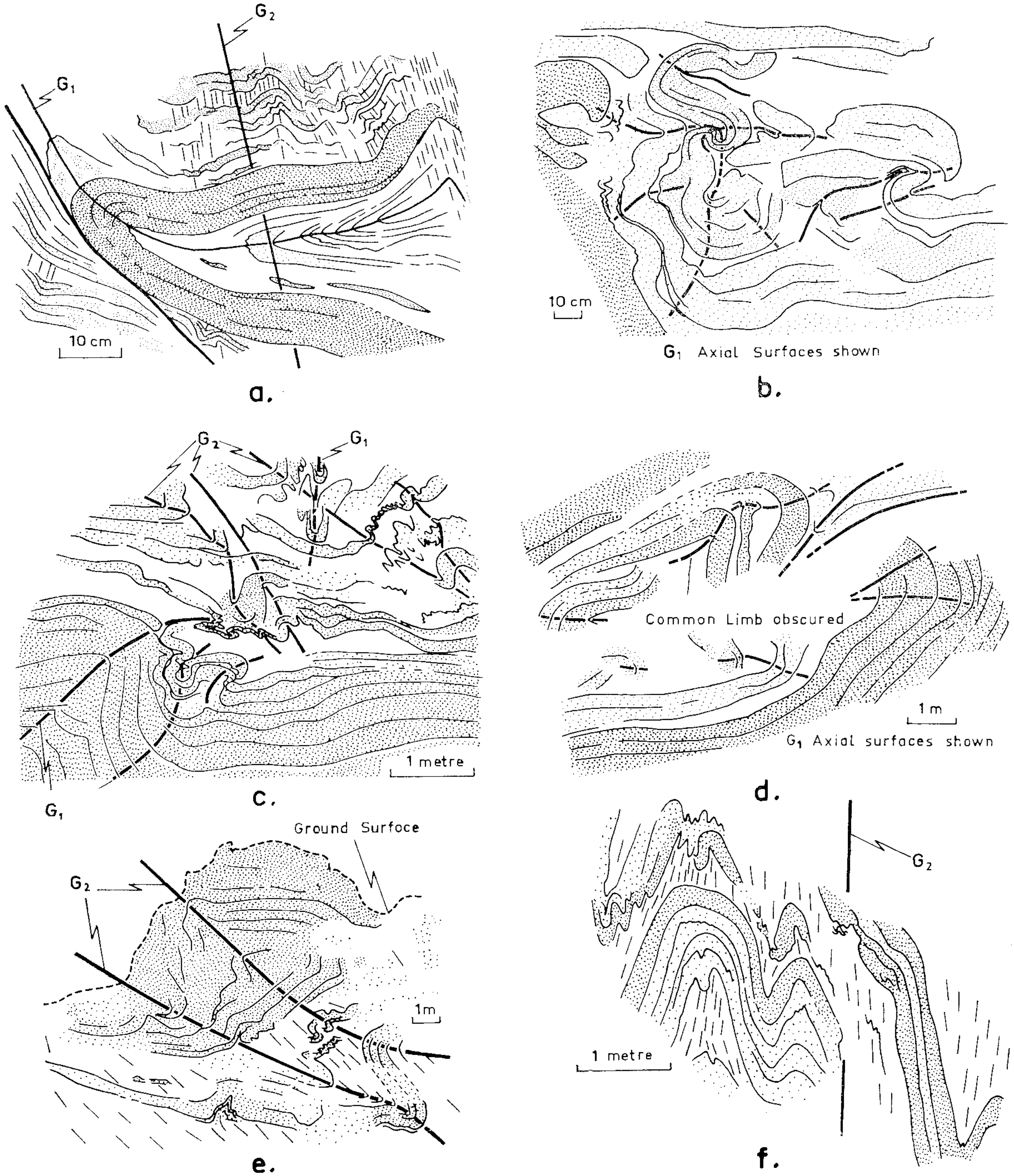

FIG. 3.—Fold profiles traced from photographs. The density of stippling is proportional to quartz %. Heavy stippling is 95% quartz; the unstippled areas are phyllite. Small dashes show traces of the G_2 cleavage. All profiles are oriented with east on the right, west on the left, and horizontal parallel to the base of the tracings. (*a*) G_1 folded by G_2. (*b*) Irregular, bulbous G_1 folds with curviplanar axial surfaces. (*c*) A larger-scale profile of the environs of the bulbous G_1 folds in (*b*). (*d*) Antiformal hinge of one of the larger-scale G_1 folds. (*e*) Large-scale quartzitic rod in the hinge of a G_2 fold in which the limbs are attenuated. (*f*) Common type of G_2 profile with transposition foliation well developed in the phyllite.

enveloping surfaces is congruous with the G_2 deformation being caused by an upwards overriding from the east—a sense of movement opposed to the movement inferred from the G_1 folds.

A foliation produced by the transposition of original psammitic and pelitic laminations in the phyllite is parallel to the axial surfaces of the G_2 folds. This transposition foliation is strongly developed in the most pelitic bands, and in parts almost obliterates the original laminations. Gravitational slip along the foliation causes some slope instability, and is a problem in engineering construction. Fortunately, the transposition foliation does not extend through quartzite layers thicker than 30 cms. Thin pelitic ribbons in the thinner quartzite layers are parallel to the G_2 axial surfaces, and cut the quartzite into slices producing a cleavage non-penetrative below the scale of mms.

Group 3 Folds

The third group, G_3, is characterized by tight, almost isoclinal folds with hinges pitching steeply in the transposition foliation. These folds are small-scale—wavelengths range from mms to dcms—and occur only in the phyllite. The profiles are almost ideally similar, but the few, thin, psammitic layers involved have the geometry of concentric folds flattened 40% to 50% perpendicular to the axial plane.

The G_3 axial planes (fig. 2*d*) dip steeply eastward as do the G_2 axial planes, but the G_3 axial planes diverge in strike by 10° to 20° in a clockwise sense from the G_2 axial planes. The sense of coupling indicated by the limbs of the G_3 folds corresponds to a subhorizontal movement of the eastern side southwards. Refolding involving G_2 structures is not common, but everywhere indicates that G_3 folds G_2. The considerable spread of the hinges in the mean axial plane (fig. 2*d*), as opposed to the more axial symmetry of G_1 and G_2, is characteristic of similar folding.

G_3 hinges are too small to measure directly in many places and are represented by a crenulation lineation. This β-lineation (fig. 2*d*) appears to be particularly useful for mapping as it is both widespread and easy to identify even in weathered outcrop, and it appears to have a consistent pitch of 50° to 60° to the north-northeast in the transposition foliation.

Kink Bands

Kink bands are common throughout the Precambrian rocks of Tasmania and are generally attributed to Palaeozoic deformation. In the vicinity of the Middle Gordon Damsite the kink bands occur mainly in the phyllite, and everywhere fold G_1, G_2 and G_3 structures. Orientations of kink bands have not been measured.

Interpretation

The style and orientation of G_1 is congruous with the hypothesis that the deformation represents considerable subhorizontal overriding of the western block towards the east. The bulbous, concentric style of the folds and the absence of well-developed cleavage indicate that this movement may have occurred early in the lithification history of the sediments.

G_2 reflects a steeply inclined thrusting of the eastern block towards the west. The penetrative, similar style of folding probably occurred in the low greenschist facies.

G_3 represents horizontal wrenching of the eastern block southwards within the phyllites. The similar style of folding and planar spread of fold hinges are consistent with the dominant mode of deformation being simple shear along the transposition foliation. G_1 may correlate with Spry's F_1 (1963), and G_2 with his F_2, but there are no conclusive data to justify such a correlation at present.

The manner in which successive deformations affect only certain zones is typical of sedimentary and low-grade metamorphic deformation in other areas (Gee, 1967, and Powell, 1967). Where such a pattern of deformation can be established orientational data can be interpreted without complex unrolling of early structures about later axes.

ACKNOWLEDGMENTS

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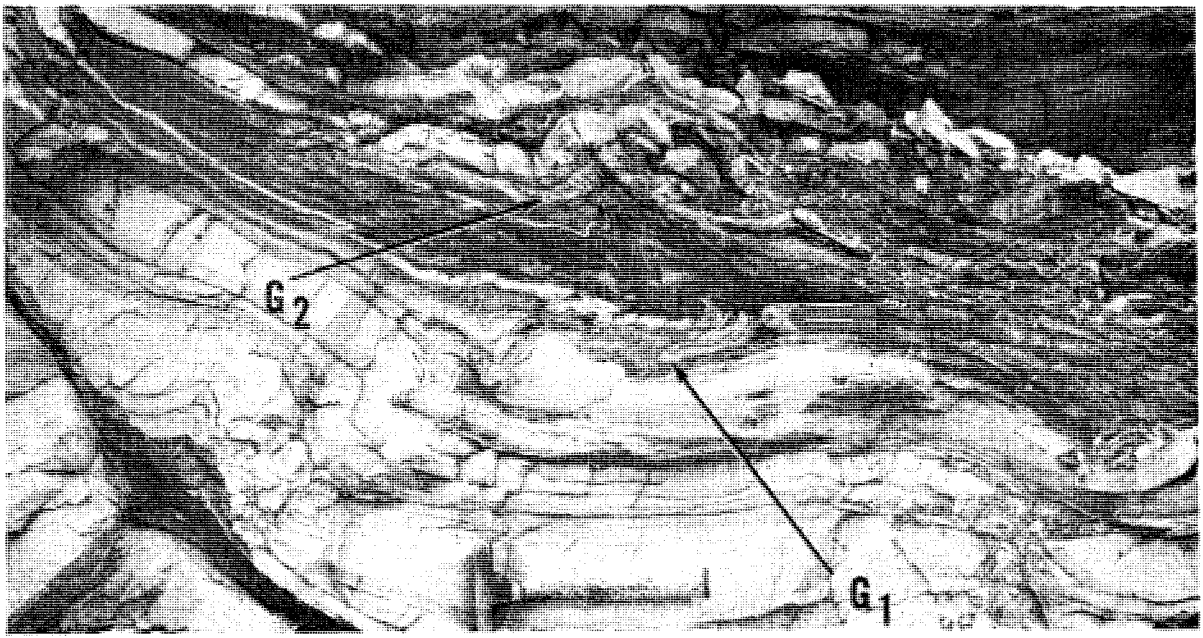
PLATE 1

No. 1.—Almost isoclinal G_1 folds with curviplanar axial surfaces folded by tight G_2 folds with planar axial surfaces.



No. 2.—G_2 folds which are well developed in phyllitic layers have not deformed the thicker quartzite bands in which there is a G_1 fold. Refolding occurs only near the hinge of the six-inch rule.

Both photographs are located in the road cut near the Middle Gordon Damsite meteorological station.

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