TECTONIC EVOLUTION OF UPPER PROTEROZOIC INGENIKA GROUP, NORTH-CENTRAL BRITISH COLUMBIA (94C/12)

By K. Bellefontaine
McGill University

KEYWORDS: Regional geology, stratigraphy, structural geology, metamorphism, Ingenika Range, Ingenika Group, Swannell Formation, Swannell fault, Swannell antiform.

INTRODUCTION

This report is a summary of a 2-year mapping project conducted in the Ingenika Range of north-central British Columbia. It incorporates and reinterprets data from Bellefontaine and Minehan (1988). The study area is located in the Ingenika Range of the Omineca Mountains (94C/12, Orion Creek). The area is bounded to the southwest and east by the Swannell River, to the northwest by Wrede Creek, and to the northeast by the Ingenika River (Figure 1-25-1).

The Ingenika Range consists of Late Proterozoic miogeoclinal rocks of the Omineca crystalline belt that extend the length of the Canadian Cordillera. To the east the Pelly fault brings similar clastic rocks of Late Proterozoic and Early to Middle Paleozoic age into contact with the older strata. In the western part of the range the miogeoclinal rocks abut the Triassic and Jurassic, probable island arc rocks, of the Lay Range assemblage and Takla Group, along the Swannell fault. In much of the Ingenika Range the miogeoclinal rocks dip gently eastwards, but near the Swannell fault the dominant structure is a northwest-plunging regional-scale postmetamorphic antiform that extends the length of the Swannell Ranges and is here referred to as the Swannell antiform.

The aim of this project was to study the structural and metamorphic history of the Ingenika Group, to investigate the nature of the faulted contact between the Omineca and Intermontane belts, to deduce the history of movement on the Swannell fault, and to determine the origin of the Swannell antiform.

Detailed structural measurements were taken along several transects across the area, and parts of the western limb of the Swannell antiform were mapped at a scale of 1:15 000.

PREVIOUS WORK

Roots (1954) defined two main stratigraphic units in the Ingenika Range and crudely delineated the major antiformal structure and metamorphic zonations of the area. Mansy and Gabrielse (1978) described and correlated a stratigraphy for Upper Paleozoic rocks in the Omineca and Cassiar mountains. More recently, Mansy (1986) completed an extensive regional stratigraphic and structural study of the miogeoclinal rocks exposed throughout the Omineca Mountains. He made broad interpretations of the structure and stratigraphy of the Ingenika Range, and mapped the distribution of metamorphic isograds around the Swannell antiform. His research also provided two geothermometers for the present study area.

The region around Chase Mountain, directly southeast of the Ingenika Range, was studied in detail by Parrish (1976a, 1976b). He documented doubly plunging structures in complexly deformed rocks at the northern edge of the high-grade Wolverine Complex. Gabrielse (1985) discussed the orientation and movement on the Swannell fault in the overall tectonic framework of the Canadian Cordillera.

STRATIGRAPHY

Rocks in the Ingenika Range belong to the Ingenika Group of the Windermere Supergroup, which forms a clastic wedge extending the length of the Canadian Cordillera (Mansy and Gabrielse, 1978). The Ingenika Group is subdivided into four formations, the lowermost of which, the Swannell Formation, is well exposed in the Ingenika Range. The Swannell Formation has been correlated with the lower part of the Horsethief Creek Group in the northern Purcell Mountains, the Kaza Group in the northern Cariboo Mountains and the middle unit of the Miette Group in the Rocky Mountains (Young *et al.*, 1973; Mansy and Gabrielse, 1978).

The stratigraphy in the Ingenika Range is dominated by monotonous sequences of variably metamorphosed micaceous schist, quartzose schist and metaquartzite, with complete gradation between these rock types. Relatively unmetamorphosed carbonaceous sandstones and grits overlie the schistose rocks.

Previous regional work by Mansy (1986) has resulted in the subdivision of the Swannell Formation into several units. Although a detailed stratigraphy for the Ingenika Range could not be established due to the absence of marker beds, the overall distribution of rock types in the area is consistent with Mansy's interpretation. The core of the antiform is dominated by schistose metaquartzites with interlayered micaceous and quartz-rich schists. The eastern limb consists mainly of thickly bedded (metre scale) grits and gritty sands with minor micaceous schist and laminated phyllite. Grits and sands, commonly with a carbonaceous matrix, together with carbonates and minor phyllites, occur along the west limb of the antiform. Rocks commonly display graded bedding and more rarely channelling.

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

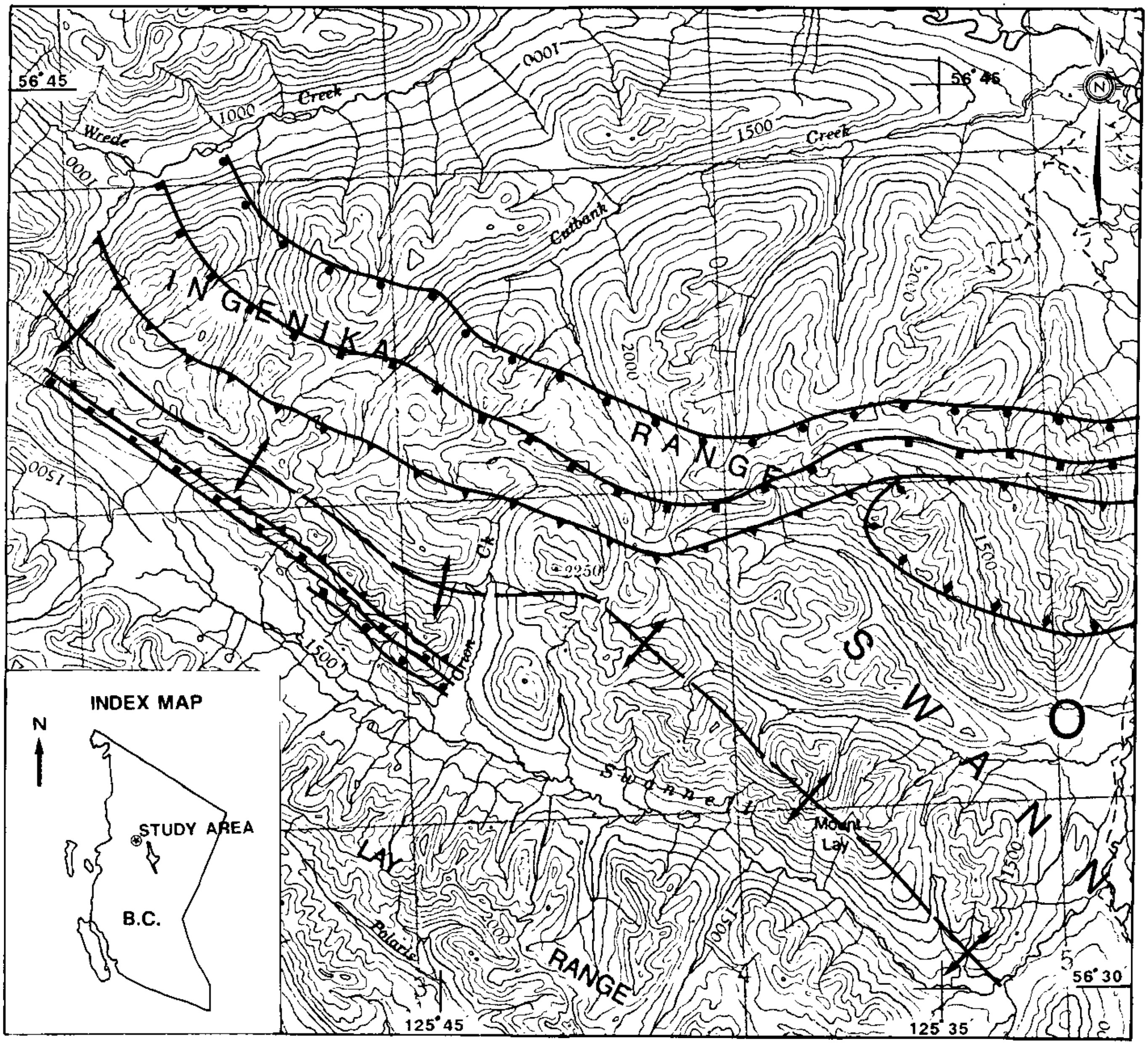


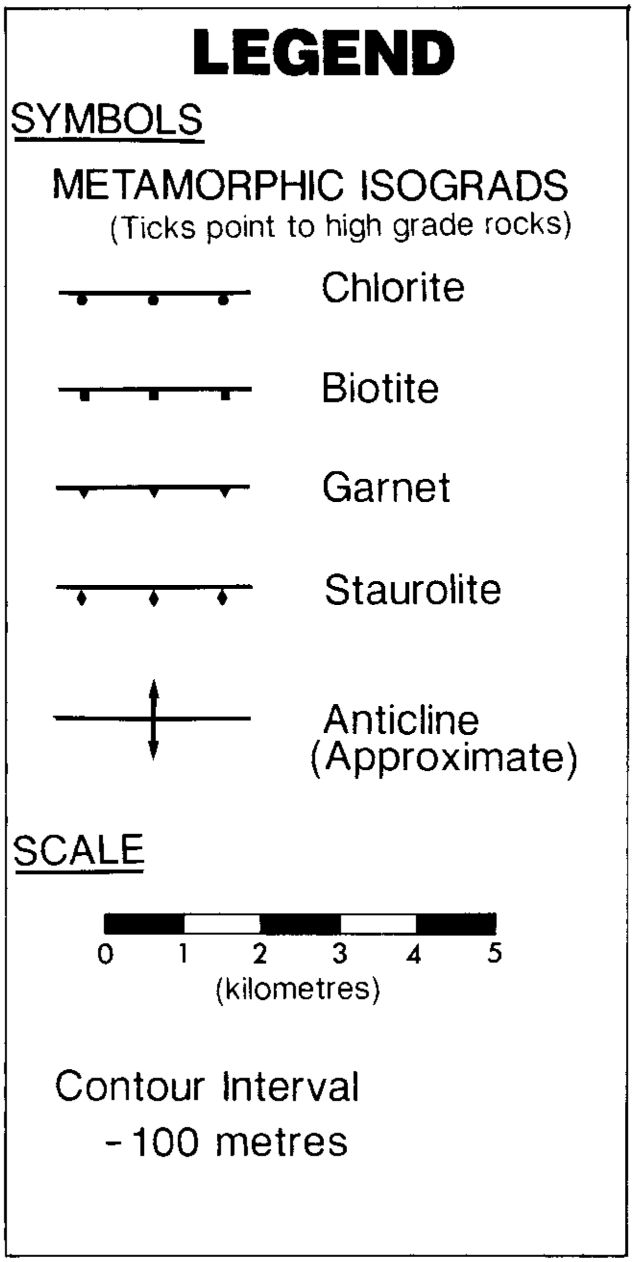
Figure 1-25-1. Location map of Ingenika Range showing D_1 metamorphic isograd distribution and approximate attitude of the axial surface trace of the Swannell antiform (after Mansy via Gabrielse, personal communication, 1987).

The thickness of the Swannell Formation is very difficult to estimate due to repetition of strata and the structural complexities of the area. The northeastern limb of the antiform is approximately 1500 metres thick and the base and top of the Swannell Formation are not exposed. Given the scarcity of outcrop-scale folds this may reflect a minimum thickness, although the possibility of tectonic thickening through bedding-parallel thrusting cannot be entirely discounted.

STRUCTURE

Ingenika Group rocks in the Swannell Ranges have experienced two major phases of deformation, followed by several late-stage events. The first phase of deformation is evidenced by typically tight to isoclinal, northwest-plunging folds with pervasive axial planar S_1 schistosities (Figure 1-25-2a). They are predominantly observed in very competent quartz-rich schists and metaquartzites in which only the noses of folds are commonly preserved (Plate 1-25-1). Outcrops consisting of isolated fold hinges, often with opposing senses of closure, are a consequence of major shearing parallel to the limbs of folds. Except for these rare F_1 closures, D_1 deformation is apparent only from bedding cleavage relationships.

All F_1 folds observed are upward facing and northeast verging, where vergence could be established. The D_1 structures are therefore compatible with a northeast-directed tectonic transport during the earliest deformation event. Since all folds observed are upward facing there is no evidence for the development of large-scale recumbent structures during



D_1 deformation. Widespread rolled fabrics in the garnets of pelitic schists indicate that metamorphism was broadly synchronous with the D_1 deformation event.

Second-phase structures are characteristically open and upright folds that are devoid of cleavage. They are associated with the Swannell antiform, which is itself a large F_2 fold. The Swannell antiform folds the metamorphic isograds associated with D_1, as well as the bedding and S_1 schistosity (Figures 1-25-1 and 1-25-2b). It has a steep southwestern limb (135/60SW), and a moderately dipping northeastern limb (120/35NE) and is weakly inclined toward the southwest with a shallow northwesterly plunge. Tight to isoclinal F_1 folds are rotated around the antiform in the same fashion as bedding and schistosity. Outcrop-scale F_2 folds were mainly observed on the southwestern limb of the antiform where they are abundant. The southwestern limb lies directly northeast of the Swannell fault and is characterized by a cascade of southwest-vergent folds, in which bedding and S_1 schistosity steepen from the regional southwest-dipping limb orientation through vertical and then turnover into shallow northeast-dipping strata that lie above slide zones (Figure 1-25-2c). These folds probably reflect drag due to southwest-vergent motion on the slide zones.

The slide planes have an average strike of 125 degrees and dip 45 degrees northeast. They are generally localized in schistose lithologies and are commonly recognized in the field by subhorizontal benches without outcrop. Since they are abundant only in the immediate vicinity of the Swannell fault, and have strikes similar to that of the fault, it is probable that they developed in association with movement on it. Therefore, these slides and their associated drag folds provide evidence for a southwesterly vergence. The fault itself is not exposed in the region and passes through the broad valley of the Swannell River. Its dip is not known with certainty, but the slide zones indicate it may dip 45 degrees northeast in this region. The Swannell fault is probably a thrust plane on which Ingenika Group rocks were transported southwest over Lay Group rocks. This conforms with the views of Mansy (1972, 1974) but differs from that of Gabrielse (1985). The simplest interpretation based on available data is that the Swannell antiform is a large drag fold associated with the same motion on the Swannell fault as on the slide planes.

Plate 1-25-1. Isolated closure of F_1 fold in metaquartzite, surrounded by quartz mica schists, looking west.

In contrast to the southwestern limb, D_2 deformation on the northeastern limb of the Swannell antiform is restricted to west-vergent, open, upright folds that are parasitic to the antiform (Plate 1-25-2) and bedding-parallel slickensides with small-scale minor folds displaying westerly vergence. F_2 folds throughout the region are broadly coaxial with F_1 folds, but are demonstrably postmetamorphic and related to deformation with a vergence in the opposite direction to that obtained in D_1. Therefore, there is little doubt they reflect a distinct tectonic event. This more brittle deformation also produced strong crenulation folds and lineations in micaceous schists. There may be more than one generation of crenulation lineations, however, the coaxial nature of the

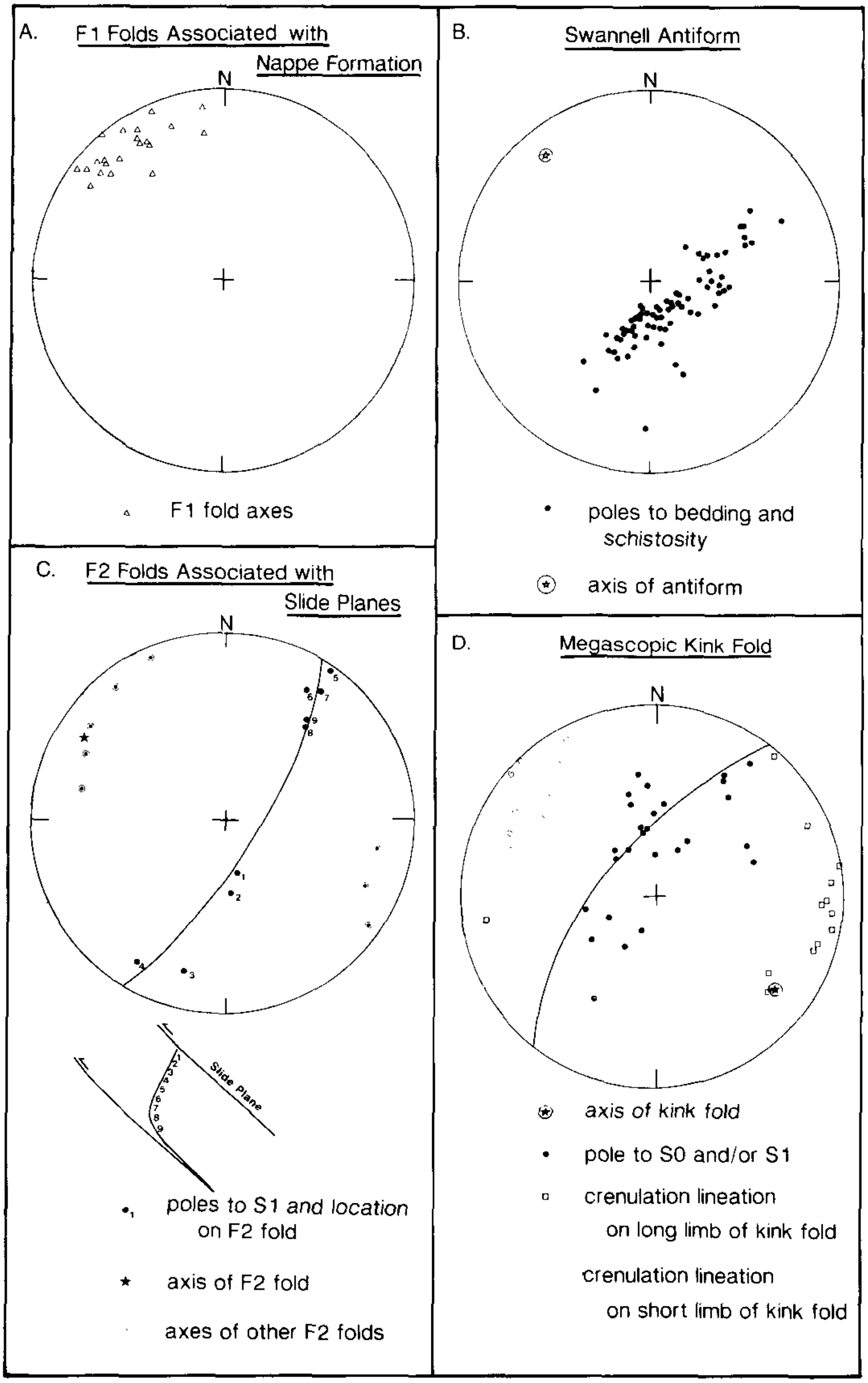


Figure 1-25-2. Equal-area stereonet plot of structural data from the Ingenika Range: (a) F_1 folds associated with east-verging nappe deformation, (b) Swannell antiform, (c) F_2 folds associated with slide planes on southwestern limb of Swannell antiform, (d) megascopic kink fold.

Plate 1-25-2. Northwest-plunging F_2 parasitic fold on northeastern limb of Swannell antiform, looking south.

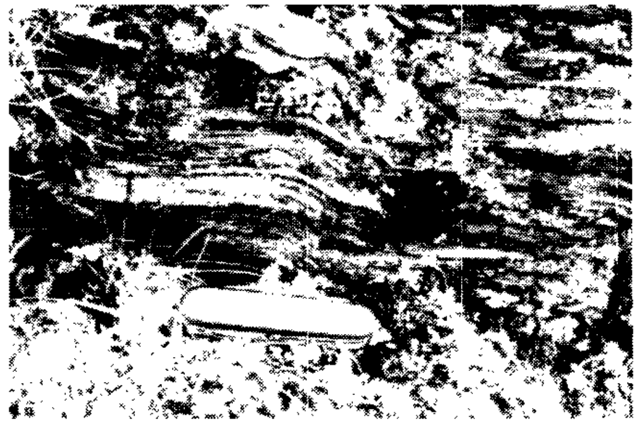


Plate 1-25-3. Small-scale dextral kink on southwest limb of Swannell antiform.

crenulations and the F_1 and F_2 fold axes makes distinction between them impossible. Refer to Figure 1-25-3 for a schematic tectonic profile of the Swannell antiform.

Sinistral and dextral kinks occur at all scales in the study area. They are concentrated on the southwest limb of the antiform and are probably related to a late-stage movement on the fault. However, interpretation of kink data is difficult since kinks are superimposed on beds of many different attitudes. Structural data for one large-scale (25 metre) kink indicates refolding of the crenulation lineation around an axis plunging 25 degrees at a trend of 140° (Plate 1-25-3), with a sense of kinking compatible with a late-stage sinistral motion on the Swannell fault.

METAMORPHISM

Regional Barrovian-type metamorphism occurred throughout the Swannell Ranges and reached at least staurolite grade in the Ingenika Range (Mansy and Dodds, 1976; Mansy, 1986). The distribution of metamorphic isograds mapped by Mansy was confirmed by mapping in the field area (Figure 1-25-1). In several places a change in metamorphic grade was found to coincide with bedding-parallel slickenside surfaces, thus implying some structural control on the position of isograds.

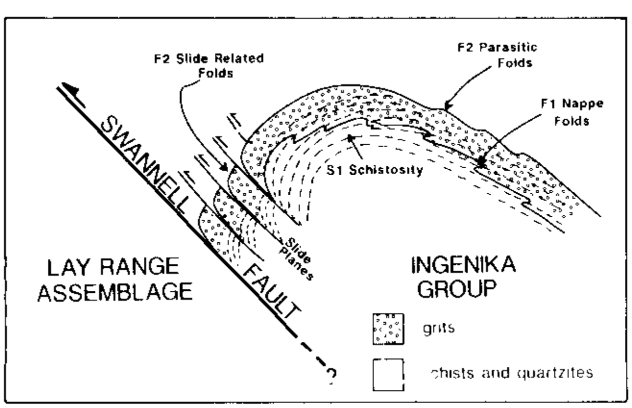


Figure 1-25-3: Schematic tectonic profile of Swannell antiform, looking northwest.

Chlorite, biotite and garnet isograds on the east limb of the Swannell antiform are evenly and widely distributed, while those on the western limb are more tightly spaced and complicated by F_2 folding. Mineralogical relationships indicate at least two phases of metamorphism, the first of which appears to be higher grade. The following observations are similar to those made by Mansy and Dodds (1976).

The first phase of metamorphism reached the highest grades and produced idioblastic staurolite up to 4 centimetres in length, and deep red garnet porphyroblasts up to 2 centimetres in diameter. The garnets frequently contain rolled fabrics indicating formation during D_1 nappe deformation. Biotite and muscovite developed along schistosity planes during this phase. Chloritic rinds and shadows around garnets reflect retrograde metamorphism.

The second stage of metamorphism is characterized by small (up to 5 millimetres), pale pink, relatively unaltered garnets, and coarse-grained biotite (up to 1 centimetre), that crosscut the D_1 schistosity. Given the apparently brittle character of D_2 deformation, the growth of these garnets probably predated D_2 and may reflect a thermal relaxation following crustal thickening during D_1 deformation.

CONCLUSIONS

The Ingenika Group in the Ingenika Range has a polyphase tectonic history. The first observed deformation involved northeast-vergent structures and synchronous regional metamorphism. The second phase of deformation is characterized by the concomitant development of the west-verging Swannell fault and the Swannell antiform. The Swannell fault in this region appears to be a west-verging D_2 thrust that places Upper Proterozoic miogeoclinal rocks of the Omineca Belt on top of Triassic and Jurassic exotic, oceanic terranes of the Intermontane Belt. Limited late kinking is compatible with late-stage sinistral motion on the Swannell fault, the extent of which is unknown.

ACKNOWLEDGMENTS

The author thanks Dr. A. Hynes for rigorous discussions in the field and review of the manuscript. Field assistance and discussion provided by K. Minehan are sincerely appreciated. This project was funded by the British Columbia Ministry of Energy, Mines and Petroleum Resources Geoscience Research Grant Program, as well as a Natural Sciences and Engineering Research Council grant to A. Hynes.

REFERENCES

Bellefontaine, K. and Minehan, K. (1988): Summary of Fieldwork in the Ingenika Range, North-central British Columbia, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork, 1987, Paper 1988-1, pages 195-198.

Gabrielse, H. (1985): Major Dextral Transcurrent Displacements Along the Northern Rocky Mountain Trench and Related Lineaments in North-central British Columbia, *Geological Society of America*, Bulletin, Volume 96, pages 1-14.

Mansy, J.L. (1972): Stratigraphy and Structure of the Ingenika Group in Finlay and Swannell Ranges, *in* Report of Activities, Part A, *Geological Survey of Canada*, Paper 72-1, pages 29-32.

——— (1974): Operation Finlay, *in* Report of Activities, Part A, *Geological Survey of Canada*, Paper 74-1, pages 17-18.

——— (1986): Géologie de la Chaine d'Omineca des Rocheuses oux Plateaux Intérieurs (Cordillère Canadienne) Son Évolution Depuis le Précambrien, Unpublished Ph.D. Thesis, *l'Université des Sciences et Techniques de Lille.*

Mansy, J.L. and Dodds, C.J. (1976): Stratigraphy, Structure and Metamorphism in Northern and Central Swannell Ranges, *Geological Survey of Canada*, Paper 76-1A, 91 pages.

Mansy, J.L. and Gabrielse, H. (1978): Stratigraphy, Terminology and Correlation of Upper Proterozoic Rocks in Omineca and Cassiar Mountains, North-central British Columbia, *Geological Survey of Canada*, Paper 77-19, 17 pages.

Parrish, R. (1976a): Structure and Metamorphism in Southern Swannell Ranges, British Columbia, *in* Report of Activities, Part A, *Geological Survey of Canada*, Paper 76-1, pages 83-86.

——— (1976b): Structure, Metamorphism and Geochronology of the Northern Wolverine Complex near Chase Mountain, Aiken Lake Map-area, British Columbia, Unpublished M.Sc. Thesis, *The University of British Columbia*, 89 pages.

Roots, E.F. (1954): Geology and Mineral Deposits of Aiken Lake Map-area, British Columbia, *Geological Survey of Canada*, Memoir 274, 246 pages.

Young, F.G., Campbell, R.B. and Poulton, T.P. (1973): The Windermere Supergroup of the Southeastern Cordillera *in* Belt Symposium, Volume 1, Department of Geology, *University of Idaho and Idaho Bureau of Mines and Geology*, Moscow, Idaho, pages 181-203.