# GEOLOGY AND STRUCTURE OF THE KOBAU GROUP BETWEEN OLIVER AND CAWSTON, BRITISH COLUMBIA: WITH NOTES ON SOME AURIFEROUS QUARTZ VEINS* (82E/4E)

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*KEYWORDS:* Regional geology, Kobau Group, stratigraphy, structure, Oliver.

## INTRODUCTION

The Fairview mining camp northwest of Oliver, British Columbia, has been the site of sporadic mineral exploration and production for over 90 years. The metal that has stimulated exploration in the past, and currently has renewed exploration interest, is gold associated with quartz veins. The quartz veins are hosted by metamorphic rocks of the Kobau Group or less commonly the Oliver and Fairview plutons (Okulitch, 1969). Despite the extensive examination of the of the camp geology, there has been little in-depth analysis of either the stratigraphy of the Kobau Group rocks or the controls on quartz vein emplacement. This study adds to present knowledge of the structural and metamorphic history of the area by concentrating on new mapping of the Kobau Group between the Oliver and Fairview plutons.

In the 1988 field season the two senior authors mapped the Fairview slopes south and west of the Oliver pluton and north and east of the Fairview granodiorite into the Similkameen Valley (Figures 1-2-1, 1-2-2 and 1-2-3). The area was mapped at a scale of 1:5000 using an orthophotographic base with 10-metre contour intervals, prepared for The Valhalla Gold Group Corporation. The study area between Cawston and Oliver covers 24 square kilometres within NTS map 82E/4E. The rationale for the study is:

- Much of the area, in particular the eastern part, has excellent bedrock exposure.
- All of the major lithologies previously described in the area are represented and well exposed, including the metamorphic rocks of the Kobau Group, and the Oliver and Fairview intrusions.
- Both the apparent stratigraphy and structure of the Kobau Group as portrayed by Okulitch (1973) are fairly simple, therefore we anticipated that many of the stratigraphic and structural relationships between units could be resolved.
- Extensive quartz veining between the two intrusions makes the area of interest for mineral exploration.

Analytical results are described in this paper with the aid of a reduced version of the completed field map (Figures 1-2-2 and 1-2-3) and accompanying cross-sections (Figure 1-2-4). The full scale version of the field map is available as an Open File (Lewis *et al.*, 1989).

## PREVIOUS WORK

The Fairview mining camp is one of the oldest exploration districts in British Columbia. Prospecting in the area began in the late 1880s and production by the early 1890s. Exploration and production continued sporadically until 1961 when the Fairview mine closed. The Fairview properties were reassessed in the early 1980s following the steep rise in the price of gold. This renewed interest has continued and is described by Crawford and Meyers (1987).

Regional geology of the area is described by Bostock (1940), Okulitch (1969, 1973) and has been reviewed most recently by Parkinson (1985). Okulitch's 1:16 000 map (1969) depicts the stratigraphy and structure of the Kobau Group and is the basis for a later publication which addresses regional geology of the Okanagan Valley (Okulitch, 1973). Sinclair *et al.* (1984) summarized field relationships and petrography of part of the Oliver pluton, focusing on the Gypo quartz vein. Parkinson (1985) concentrated on the geochronometry and regional geology of the southern Okanagan Valley. He investigated the petrologic variations within the Oliver pluton and the uranium-lead geochronometry of intrusions west and east of the Okanagan Valley fault. Finally, Godwin and Gabites (1988) have reported preliminary lead isotope work on mineralized quartz veins in the abandoned Susie mine in the Oliver pluton, and the reopened Stemwinder mine in the Kobau Group rocks.

## GENERAL GEOLOGY

The map area lies within the Intermontane tectonic belt and the Quesnellia terrane (Armstrong, 1988). The area is underlain dominantly by polydeformed, regionally metamorphosed rocks of the Kobau Group (Bostock, 1940). The Kobau Group is areally restricted to the southern Okanagan Valley and is bounded by the Similkameen Valley to the west and the Okanagan Valley fault to the east. The age of the Kobau Group rocks is uncertain; however, they have been inferred to be post-Devonian to pre-Cretaceous in age and are intruded by Jurassic and, locally, mid-Cretaceous plutons (Okulitch, 1973). These inferences are based on similarities in lithology and in degree of deformation and metamorphism of dated rocks in adjacent areas.

Okulitch (1969, 1973) described Kobau Group rocks as highly deformed, low-grade metamorphic quartzite, phyllite, schist, greenstone and marble, and delineated nine mappable units comprising a 1900-metre structural succes-

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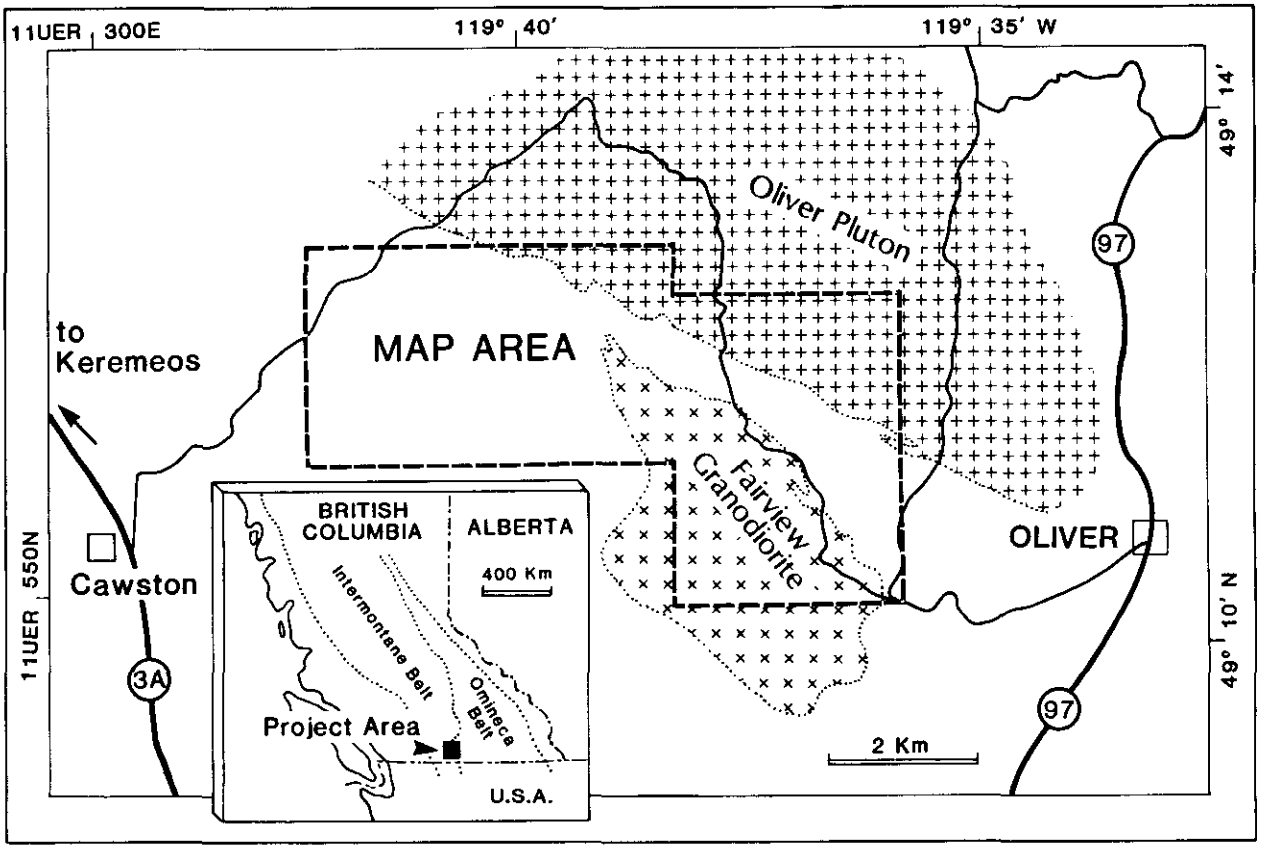


Figure 1-2-1. Location map of the project area. Inset shows relationship of the map area to regional geology.

sion. He assumed that at least one of the lithologies (phyllite-marble assemblage, Unit 6) occupies a single stratigraphic horizon and that there were no facies variations or unconformable relationships between lithologies within the Kobau Group. These assumptions were crucial to his interpretation of the structure and stratigraphy of the Mount Kobau geology and much of the structural complexity that appears on his map hinges on them.

Okulitch (1973) described three phases of folding within the Kobau Group. He recognized an initial phase of folding which was coincident with the regional metamorphism, whereas the later structures were interpreted to be related to the intrusive activity.

# STRATIGRAPHY

## INTRUSIVE ROCKS

In the Fairview mining camp the Kobau metamorphic rocks host two intrusions; the Fairview granodiorite and the Oliver granite (Figure 1-2-1). The age of the Fairview intrusion is constrained by geochronometry (potassium-argon radiometric age on biotite) to be older than 111 ± 5 Ma (unpublished date, courtesy R.L. Armstrong). The Oliver pluton crops out in the northeastern part of the map area and clearly cuts the lithologies and structures of the Kobau Group. In addition to the younger Fairview and Oliver plutons, the metasedimentary-volcanic package is cut by aplite dykes, small granitic, dioritic and mafic stocks, auriferous quartz veins which are most likely associated with the Jurassic intrusions, and Tertiary (White *et al.*, 1968), northeasterly trending mafic dykes. Some mafic or lamprophyric dykes within the metasedimentary rocks might be considerably older. Plagioclase-quartz-phyric biotite dacite dykes ("quartz latite" of Okulitch, 1969, 1973) occur in swarms within the Kobau Group rocks east of the Fairview intrusion (Lewis *et al.*, 1989). The dykes are parallel to the regional compositional layering in the Kobau Group, display a distinct foliation, and were subject to low-grade (contact?) metamorphism. Their age is uncertain, possibly older than the Jurassic intrusions, but certainly younger than the major pre-Jurassic deformation.

The Oliver pluton is heterogeneous (Parkinson, 1985) and comprises several distinct lithologies including biotite-hornblende diorite, porphyritic biotite granite, garnet-muscovite granite, porphyritic quartz monzonite and syenite. The map area is dominated by porphyritic granite and quartz monzonite phases with lesser amounts of diorite, syenite and muscovite granite. Mineralogically and chemically the Oliver pluton has affinities with S and I-type granitic rocks. The age of the pluton is based on a uranium-lead zircon date of 152 ± 3 Ma and a rubidium-strontium whole-rock date of 157 ± 8 Ma obtained on the youngest phase of the intrusion (Armstrong and Ryan, unpublished as cited by Parkinson, 1985).

## LAYERED ROCKS OF THE KOBAU GROUP

The Kobau Group rocks comprise banded, foliated quartzite lithologies with minor mafic schists and thick, compositionally layered mafic schist units with intercalated quartzite bands, as well as metacarbonates and minor mafic metavolcanic flows or sills. Our proposed stratigraphy is summarized in a table of formations (Table 1-2-1). Although "tops" cannot be established, a structural section approximately 1500 metres in thickness can be documented across the map area. The structurally lowest rocks consist of a mafic schist containing thin (less than 10 metres) marble boudins and rare mafic sills and flows (KM1, Figure 1-2-1, Table 1-2-1). This schist is structurally succeeded by a banded quartzite (KQ1), which in turn is overlain by a second mafic schist and quartzite sequence (KM2 and KQ2). The lithologies of the quartzite units 1 and 2, as well as mafic schist 1 and 2, differ sufficiently to warrant these different structural positions. Our proposed structural succession differs from previous work (Okulitch, 1973) mainly in recognizing that mafic schist units containing marble lenses occur at more than one stratigraphic level.

The regional metamorphism of the Kobau Group in the study area appears to be synkinematic with respect to the main phase of pre-Jurassic deformation. The metamorphic grade did not exceed greenschist facies documented by actinolite-biotite-epidote-albite assemblages in mafic schists and calcite-tremolite assemblages in some carbonate rocks. Garnet is locally observed in semipelitic layers indicating that its presence or absence is largely controlled by bulk composition. The contact metamorphic overprint resulting from Jurassic intrusions is not obvious and merely obscured schistosities near intrusive contacts with secondary, unoriented growth of greenschist minerals. The protolith of Kobau Group rocks near Oliver is interpreted as thick successions of marine, fine-grained, stratified volcaniclastic sediments of predominantly mafic composition (mafic schists) with intercalated quartzofeldspathic sediments, minor limestones and abundant ribbon chert sequences (layered quartzite). Minor basaltic volcanic rocks occur as flows or sills. The sediments may have formed in a volcanic arc or eugeoclinal setting, distal to volcanic centres.

# STRUCTURAL GEOLOGY

## KOBAU GROUP

Metasedimentary rocks of the Kobau Group record a structural history involving at least three discrete folding events and later brittle faulting. The earliest structures preserved comprise isoclinal folds of compositional layering and an axial planar foliation defined by parallel alignment of platy and elongate minerals. Together, these represent a regional transposed foliation which dips moderately to steeply to the northeast, except in the Similkameen slopes area where it is reoriented about later structures. Flattening across the foliation is evident from boudinage of competent quartzite and marble lithologies and discontinuous stratigraphic contacts. Isoclinal folds typically have attenuated limbs and moderate thickening in hinges. These folds are limited to the mesoscopic scale, and total structural thickening attributed to them is uncertain. Fold axes plunge to the northeast and

TABLE 1-2-1
TABLE OF FORMATIONS

| Period | Formation | Lithology |
|---|---|---|
| Tertiary, *ca.* 50 Ma | Mafic dykes | Prophyritic mafic dykes (augite, plagioclase, hornblende, biotite); some aphyric. |
| Jurassic(?) | Auriferous quartz veins | Veins near the Oliver pluton; veins within the Oliver pluton; generally massive, jointed, some ribboning; sulphide-poor; age relative to Fairview intrusion unknown. |
| Jurassic | Granitic, dioritic dykes and stocks | Aplite, aplitic granite, minor diorite and hornblende diorite; dykes and small stocks bordering the Oliver pluton or within Kobau Group rocks. |
| Jurassic, *ca.* 155 Ma | Oliver pluton (JOqm) | Complex, multiphase intrusion; K-feldspar-phyric quartz monzonite, granite and minor syenite; locally foliated border facies; locally agmatitic margin |
| Jurassic(?) | Auriferous quartz veins (qz) | Vein systems along Fairview intrusion; sulphide-poor, locally containing pyrite, galena, sphalerite, chalcopyrite, graphite; commonly ribboned. |
| Jurassic(?) | Fairview granodiorite (JFgd) | Weakly foliated hornblende-bearing biotite granodiorite with minor granite and diorite; chlorite alteration common. |
| Pre-early Jurassic | Dacitic dykes | Plagioclase-quartz-phyric biotite dacite or plagidacite weakly foliated; 0.5-10 m thick; low-grade metamorphic overprint. |
| Pre-Jurassic | | Polyphase deformation and metamorphism. |
| Pre-Jurassic | Kobau Group (KM1) | Tops unknown, listed from east to west.<br>Mafic schist 1: Alternate mafic layers (actinolite, biotite, epidote, minor feldspar, quartz, chlorite) and quartzose or feldspathic layers (actinolite, biotite, epidote, sphene, calcite, white mica (mm-cm);<br>some carbonate-rich sections (calcite, tremolite, epidote, feldspar, quartz);<br>sections of quartz-feldspar-biotite schist: alternate biotite-rich (feldspar, quartz, epidote) and quartz-feldspar-rich (minor biotite, calcite) layers (mm-cm);<br>lenses (1-50 m) of layered, foliated quartzite with thin biotite-rich laminae;<br>boudins of massive quartzite;<br>sections of uniformly mafic composition (10-100 m);<br>calcite-marble boudins (2-15 m);<br>rare lenses of augite-porphyritic mafic metavolcanic flows<br>flows or sills (relict augite, actinolite-chlorite-epidote matrix). |
| | (KQ1) | Quartzite 1: Quartzite layers (1-5 cm) separated by biotite-rich layers (mm-cm), foliated; some biotite-rich sections; lenses of mafic schist. |
| | (KM2) | Mafic schist 2: Similar lithologies as in mafic schist 1;<br>black, foliated biotite-quartzite;<br>lenses of mafic metavolcanic flows or sills, coarse bedded, weakly foliated, primary textures obliterated;<br>calcite marble (5-25 m) and minor calcite-tremolite marble. |
| | (KQ2) | Quartzite 2: Foliated quartzite with biotite-rich laminae, interbedded sections of mafic schist (1-20 m). |

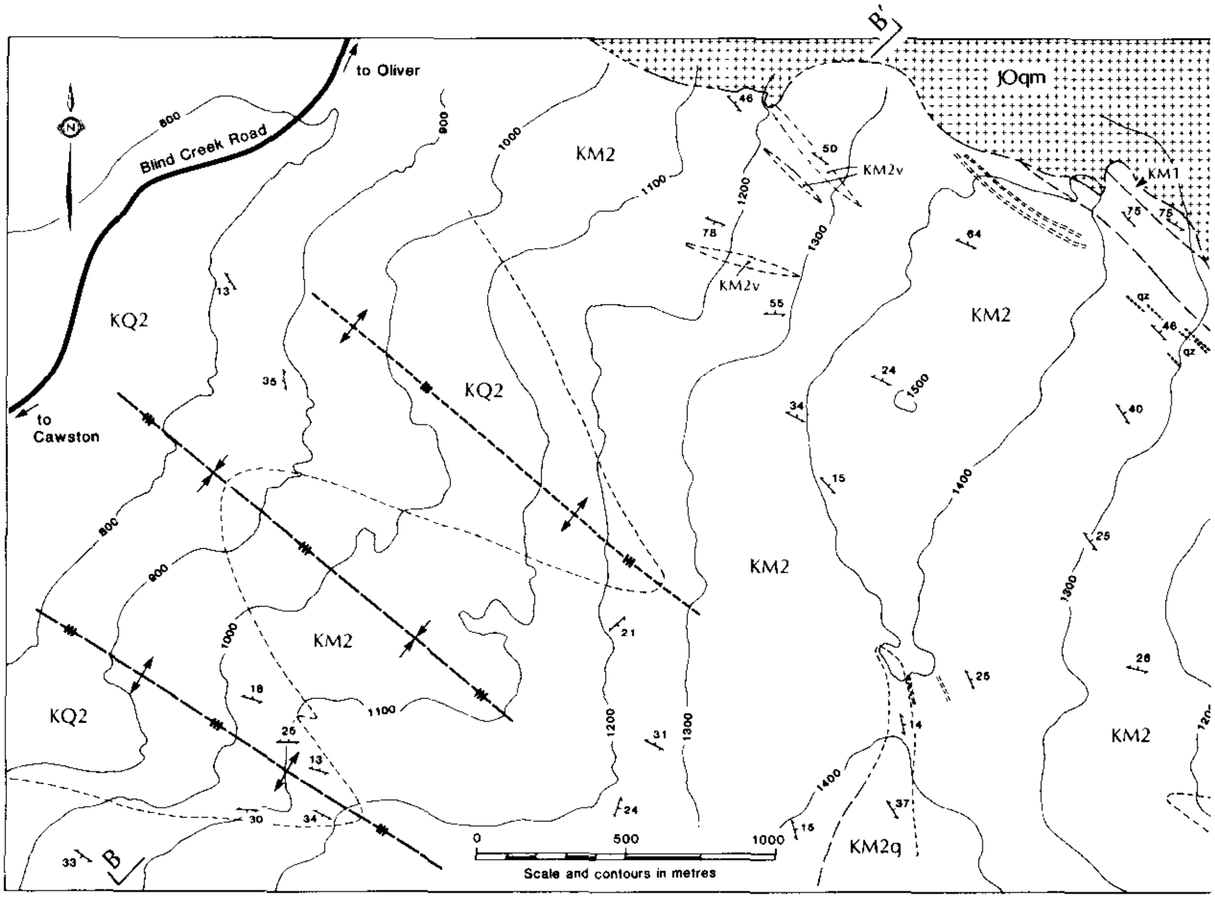


Figure 1-2-2. Simplified geological map of the western part of the project area (after Lewis *et al.*, 1989).

northwest, and no consistent patterns of vergence direction are observed.

The transposed foliation is refolded on all scales about second phase, tight to isoclinal structures with axial planes at low angles to the regional fabric. Mesoscopic folds occur in all quartzite and schist lithologies and, in some locations, have a weak associated crenulation cleavage. Fold axes consistently plunge steeply to the east-northeast and there is a moderate thickening of layers in hinge regions. Second phase map-scale folds are obscured by flattening in hinge regions and the discontinuous nature of the stratigraphy, but several are recognizable on the basis of stratigraphic repetition and vergence changes of mesoscopic folds. The most significant of these locally inverts a section at least 1000 metres thick in the Oliver slopes area; other map-scale closures are second order to this structure and only locally invert stratigraphy (Figure 1-2-4).

A third folding event formed megascopic open buckle folds which are limited to the Similkameen slopes area. These folds have very angular hinge regions, are mapped by abrupt changes in orientation of compositional layering and are not observed mesoscopically. Fold axes plunge shallowly to the northwest or southeast, with subvertical axial planes. Fold amplitude decreases rapidly to the southeast and mappable folds disappear completely near the contact with the Fairview granodiorite. Finally, a series of steeply dipping, north-trending faults locally offsets stratigraphic contacts on the Oliver slopes. Fault-plane grooves and offsets of recognizable markers indicate that the dominant motion on these surfaces was subhorizontal, left-lateral.

Quartz veins are ubiquitous in metasedimentary rocks and display varying degrees of deformation according to their age. Earliest formed veins are completely transposed into the regional foliation, whereas later structures maintain a planar geometry and cut all structural elements.

## INTRUSIVE ROCKS

Intrusive contacts of the Oliver and Fairview plutons crosscut phase one and phase two folds, and their relationship to third phase structures is unclear. Structures within the plutons are limited to strong foliations along the margins of the Fairview pluton and strike-slip faults within both plutons. It is uncertain whether the foliation is igneous or tectonic in origin but intrusion postdates the major deformational events seen in Kobau Group rocks. The dacitic dykes contain a foliation parallel to the regional compositional layering; all other dykes lack internal deformation. Veins within the intrusive rocks are undeformed and are localized along fault zones.

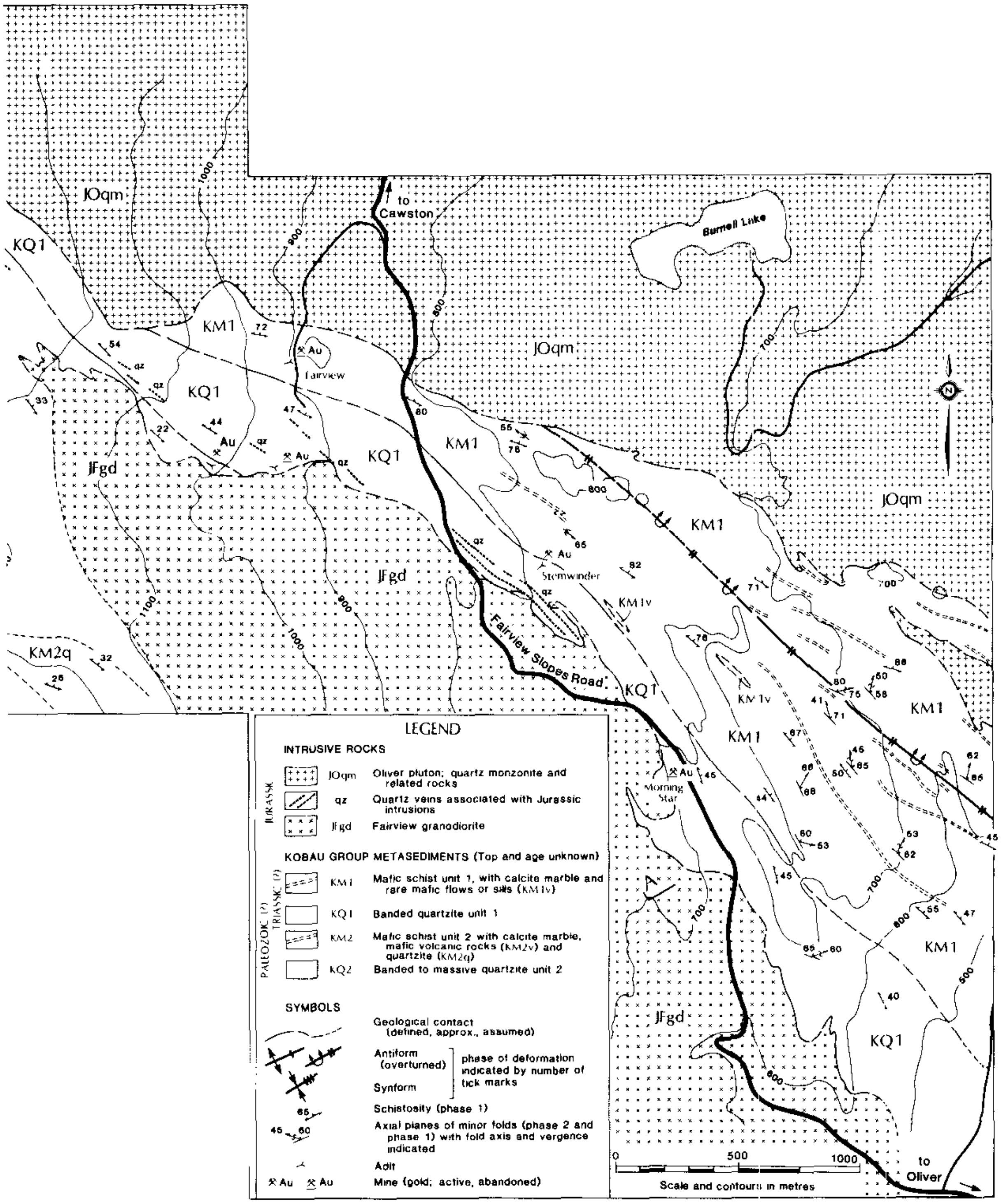


Figure 1-2-3. Simplified geological map of the eastern part of the project area (after Lewis *et al.*, 1989).

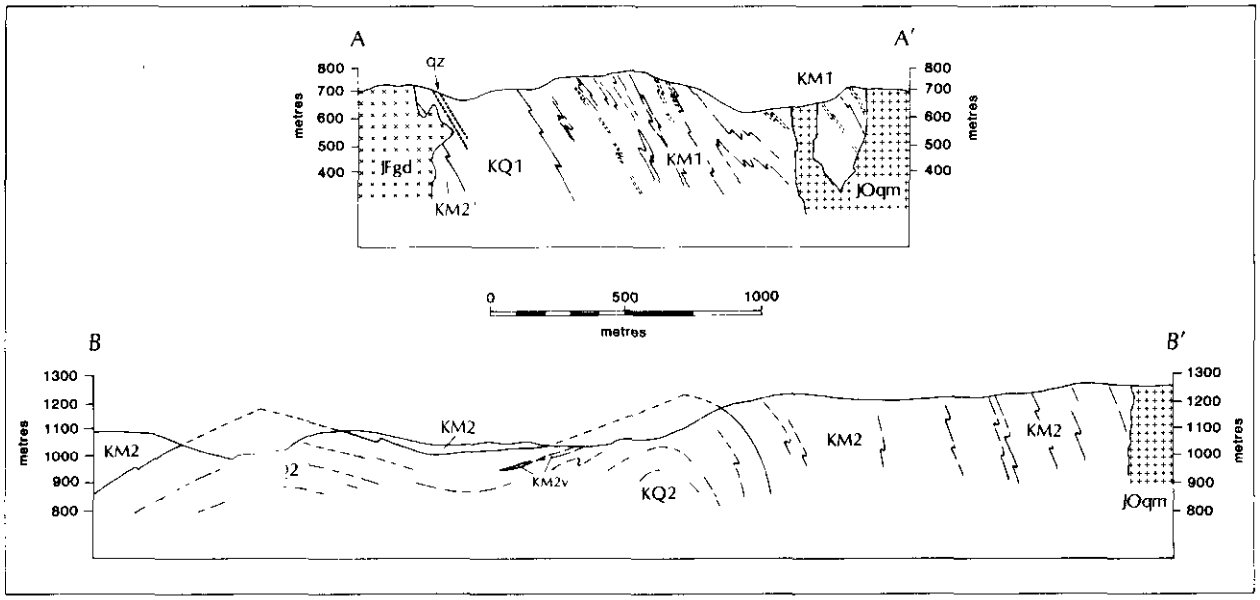


Figure 1-2-4. Geologic cross-sections A-A′ and B-B′. Lines of section are shown in Figures 1-2-2 and 1-2-3.

## AURIFEROUS QUARTZ VEINS ASSOCIATED WITH THE FAIRVIEW GRANODIORITE

Auriferous quartz veins occur within the Kobau Group adjacent to and parallel to the Fairview granodiorite contact (Figures 1-2-2 and 1-2-3). Near the Stemwinder mine, these veins form two sets at distances of approximately 50 metres and 100 metres from the intrusive contact. Further to the northwest, near the Fairview mine, veins occur at structurally higher levels near the contact between quartzite (KQ1), and mafic schist (KM1) map units, as well as close to or within the granodiorite. A third class of veins is associated with small granitic and aplitic stocks. These veins lie along strike and parallel to the quartz veins associated with the Fairview granodiorite. All veins are locally concordant to the regional foliation but cut lithologic contacts at the map scale and, in at least one outcrop, are found within intrusive rocks of the Fairview pluton. In general, they form planar bodies striking northwesterly and dipping to the northeast. Individual veins pinch and swell greatly, attain thicknesses up to 5 metres and may be traced up to 500 metres along strike.

Within veins, centimetre-scale banding, marked by concentrations of oxides, sulphides and graphite, is parallel to vein contacts. A strong parting, with spacing varying from 1 centimetre to 1 metre, also parallels vein contacts. These parting surfaces bound rare angular wallrock fragments up to 20 centimetres thick. Slickensides with shallow southeast plunges mark some parting surfaces, and uncommon stylolites are at moderate angles (10 to 50°) to vein walls.

The spatial relationship between the quartz veins and the Fairview pluton suggests the two may be genetically related. Spaced parting surfaces and wallrock fragments within the veins indicate they formed by accretion through the crack-seal mechanism of vein growth (Ramsay, 1980). Preliminary lead isotope studies indicate the mineralization associated with quartz veins is younger than or as young as the Oliver pluton (Godwin and Gabites, in preparation). Additional research, currently in progress, is directed at measuring the lead isotope signature of feldspars in the Oliver pluton.

## CONCLUSIONS

Several new conclusions have arisen from the 1988 field mapping. Firstly, similar lithologies occupy a number of different stratigraphic levels. This makes reconstruction of the original Kobau Group stratigraphy difficult, if not impossible. In this regard our interpretations are at odds with some of the basic assumptions made by Okulitch (1973). Secondly, field mapping has clarified some of the age relationships and structural controls related to the emplacement of mineralized quartz veins. However, there remain a number of fundamental questions concerning the geology of the Fairview slopes area that this study has been unable to answer. These include:

(1) The relationship between this stratigraphy and the stratigraphic successions found to the south at Mount Kobau.

(2) The relationship between the sequence of deformational events described here and the regional geologic history.

(3) The absolute ages or age relationships between deformational events, metamorphism and intrusive activity.

These problems could be addressed by further research involving additional geologic mapping, detailed petrographic work involving microfabric analysis to constrain the deformational history of this group of rocks, and a geochronological and paleontological study to complement our inferred age relationships.

## ACKNOWLEDGMENTS

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# NOTES