STRUCTURE OF THE TAKLA GROUP EAST OF THE FINLAY-INGENIKA FAULT, McCONNELL CREEK AREA, NORTH-CENTRAL B.C.

(94D/8, 9)

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INTRODUCTION

The study area is located northwest and south of Johanson Lake, bounded to the northeast by the northwest-trending Lay fault and to the west by the north-northwest-trending Finlay-Ingenika fault. The Finlay-Ingenika fault is a dextral transcurrent fault, and is part of the very prominent strike-slip fault system in north-central British Columbia (Gabrielse, 1985). This project was undertaken to examine the structures on the east side of the Finlay-Ingenika fault, to provide geological evidence for the dextral transcurrent displacement and to study local deformation associated with it.

This report summarizes the results of 1:50 000-scale geological mapping in July and August 1990 in parts of map sheets 94D/8 and 94D/9. Fieldwork concentrated on stratigraphic and structural relationships.

GEOLOGICAL SETTING

The study area is in the Intermontane Belt of Monger (1984), and forms part of the Quesnellia tectonostratigraphic terrane. North and south of the study area, rocks of Quesnellia are separated from Stikinia rocks to the west by the Cache Creek Terrane, which is generally regarded as a subduction-related assemblage. These terranes were amalgamated by latest Triassic to earliest Jurassic time, to form a large, composite terrane, Terrane I, that accreted to the ancient margin of North America in Jurassic time (Monger, 1984). There is widespread evidence of dextral transcurrent motion of Terrane I, and possibly part of the Omineca metamorphic belt, during the late Cretaceous (Gabrielse, 1985) and some workers have advocated as much as 2400 kilometres of transport (*e.g.* Umhoefer, 1987). The Finlay-Ingenika fault, the boundary between Quesnellia and Stikinia in the project area, is one of the system of dextral strike-slip faults on which the motion occurred.

The area is underlain predominantly by Upper Triassic Takla Group volcanic, volcaniclastic and sedimentary rocks. West of the Finlay-Ingenika fault the Takla Group was subdivided during 1:250 000 mapping of the McConnell Creek map area (Lord, 1948; Church, 1974, 1975; Richards, 1976a, b; Monger, 1977) into a lower Dewar Formation consisting of volcanic sandstone, siltstone and black argillite, a middle Savage Mountain Formation of dark grey-green basalt, volcanic breccia and siltstone and an upper Moosevale Formation, consisting of red and green or reddish grey marine and nonmarine volcaniclastics together with intermediate alkaline feldspar porphyry (Monger, 1977). Takla Group east of the Finlay-Ingenika fault remains undivided. It is dominated by grey green, dark and pale grey volcanic breccia, sandstone and siltstone, interbedded with minor augite and feldspar-porphyritic lava flows, with minor black argillite and dark grey and purplish grey limestone. No conclusive stratigraphic correlations have been made between the Takla Group rocks on either side of the fault, and Minehan (1989b) has suggested that the rocks east of the fault should be assigned to a different group (Johanson Group) because they are geochemically very different (calcalkaline rather than alkaline) from the western Takla Group, despite their similar appearance.

LOCAL STRATIGRAPHY

The Takla Group east of the Finlay-Ingenika fault is predominantly volcaniclastic, with minor volcanic and sedimentary rocks. Stratigraphic successions and rock assemblages vary greatly from one locality to another. The stratigraphy and petrology are therefore described separately for three different regions of the map area: the northwest, southwest and southeast (Figure 1-12-1).

The stratigraphic succession in the Wrede Range in the northwest has been described by Bellefontaine and Minehan (1988) and Minehan (1989a, b). The typical stratigraphic section occurs within Minehan's (1989a) Block C. It attains thicknesses of up to 1800 metres and can be divided into four units (Figure 1-12-2a).

A lowest Unit 1 has a minimum thickness of about 800 metres but the base is not exposed. The lowest part of this unit is exposed along a small northeast-trending ridge in the south of the region and is dominated by dark green and greenish grey, massive volcanic breccia, sandstone and siltstone, together with minor clinopyroxene or plagioclase-porphyritic lava flows. The dark grey to greenish grey breccia is compositionally heterogeneous. There are crystals of plagioclase and clinopyroxene together with fragments of porphyry, volcanic sandstone and siltstone. The fragments are angular to subrounded, and average less than 10 centimetres in diameter. The breccias are poorly bedded and poorly sorted. The grey-green volcanic sandstone is com-

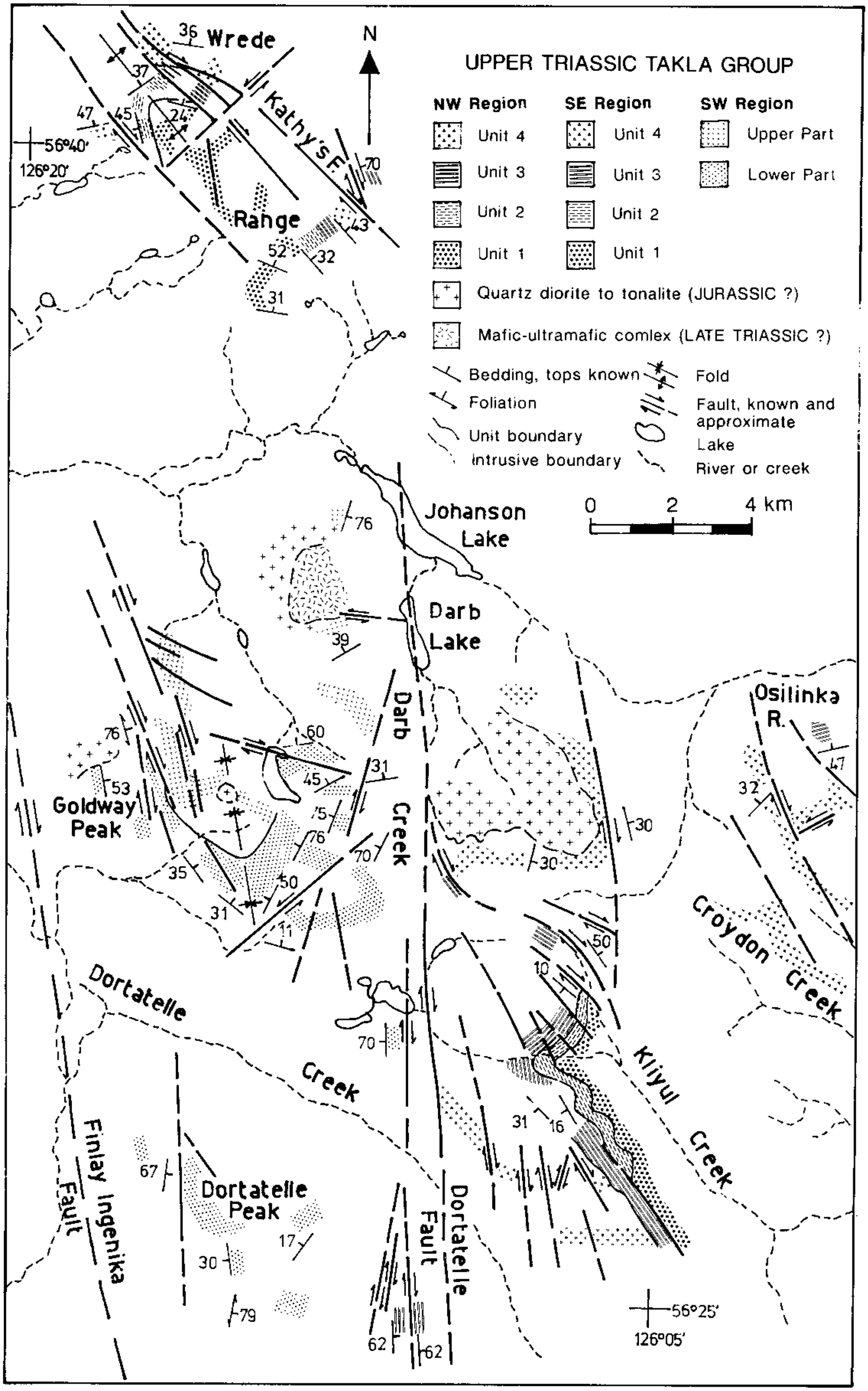

Figure 1-12-1. Generalized geology of the Johanson Lake area.

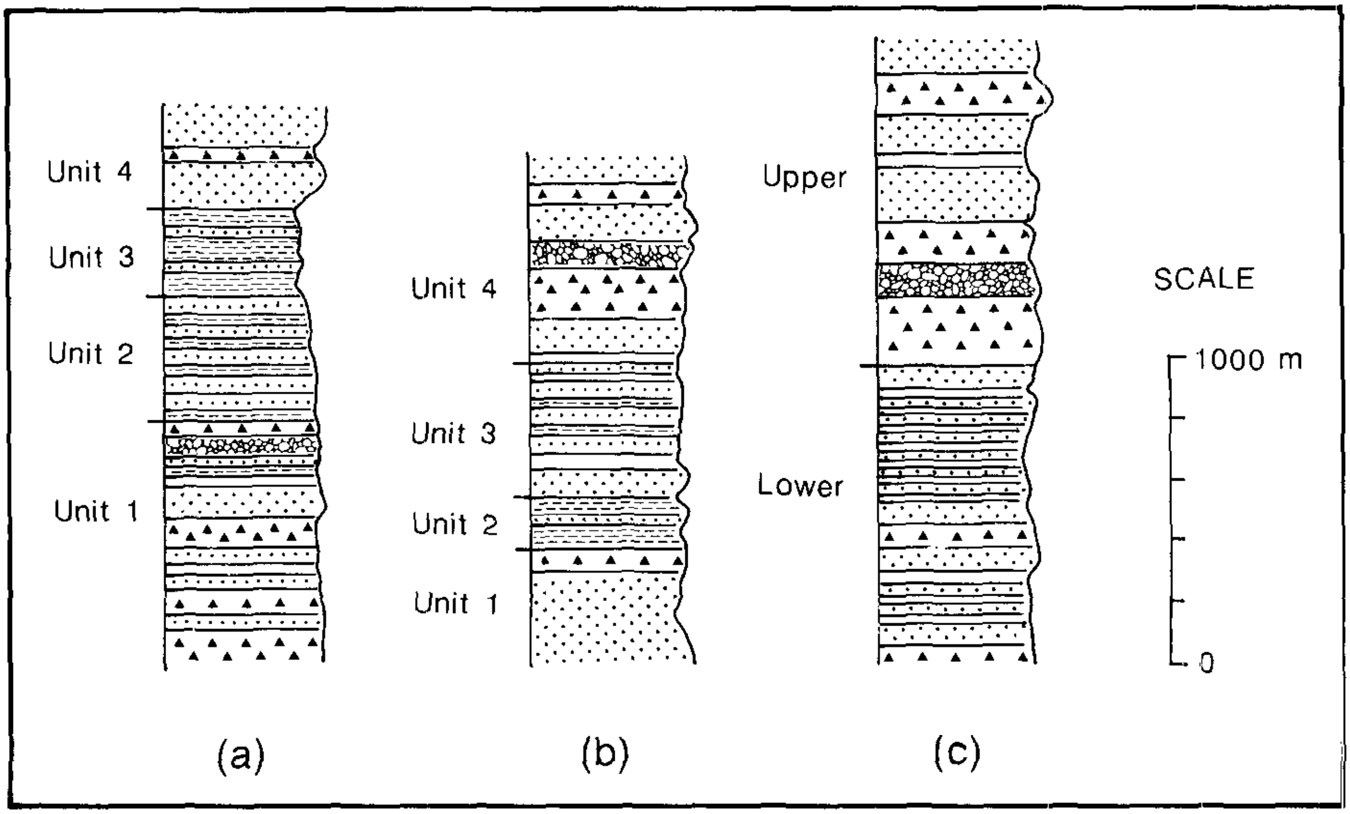

Figure 1-12-2. Generalized stratigraphic columns of Takla Group in the northwest (a) southeast (b) and southwest (c) regions. Triangles: volcanic breccia; dots: volcanic sandstone; horizontal lines: volcanic siltstones; dashed horizontal lines: black argillite and limestone; irregular circles: lava flows.

posed predominantly of plagioclase, amphibole and clinopyroxene crystals, with minor small lithic fragments similar to those in the breccia. It may occur as graded, upward-facing beds, typically 20 centimetres thick, or as massive units up to 300 metres thick. Volcanic siltstone is minor, greenish or pale grey, and commonly shows very fine, alternating dark and pale grey laminations, presumably reflecting alternation of clinopyroxene/amphibole and plagioclase-rich layers. Clinopyroxene and clinopyroxene-plagioclase-porphyritic flows are greenish grey, dark grey or dark purple and are characterized by equant euhedral clinopyroxene and anhedral plagioclase phenocrysts typically up to 5 millimetres long but locally as long as 1 centimetre. Commonly, clinopyroxene is fresh, dark green to pale greenish yellow and displays sector twinning and pseudodimetric shape in cross-section. These lava flows closely resemble the breccia in the field but are distinguished by the complete absence of fragmentation, even on the weathered surfaces.

The middle part of Unit 1, exposed on the col to the northeast, consists of greenish grey and pale grey volcanic sandstone and siltstone interbedded with black, reddish weathering, thin-layered argillite and purplish grey limestone with individual beds up to 30 centimetres thick. The upper part of Unit 1 consists of characteristically greenish grey, massive lava flows of clinopyroxene and clinopyroxene plagioclase porphyry and volcanic sandstone. The flows contain fragments of purple limestone typically 10 to 20 centimetres and locally up to 2 metres in diameter. It is therefore likely that the lava flow disrupted the limestone of the middle part of the unit.

Unit 2, up to 400 metres thick, is well exposed along the northeast-trending ridge northeast of Unit 1. This unit is made up of greenish grey and pale grey, well-bedded volcanic sandstone and siltstone interbedded, with black, thin-layered argillite and marly limestone. The sedimentary rocks account for about 40 per cent of the unit and individual argillite beds are typically 2 centimetres thick. Toward the top of the unit sedimentary rocks become progressively more abundant.

Unit 3, a predominantly sedimentary package about 270 metres thick, consists mainly of black, reddish weathering, thin-layered argillite and dark grey or black, thin-layered, marly limestone. Thirty per cent of the unit is thick-bedded (40 to 50 cm), greenish grey and dark grey volcanic sandstone and siltstone.

Unit 4, the uppermost unit of the succession, is exposed on the highest peak in the southern part of the region. It is dominated by massive, greenish grey volcanic sandstones and has a minimum thickness of 300 metres. To the northeast this unit is cut by the northwest-trending Kathy's fault (Figure 1-12-1).

In the southeastern region, west of Kliyul Creek, four units are recognized and a minimum thickness of 1600 metres is estimated for the whole succession, although the estimate is imprecise because of widespread shearing and fault truncation at its top. Thicknesses of Units 2 and 3 have been well defined and measured (Figure 1-12-2b).

Unit 1, exposed along the west side of Kliyul Creek, is dominated by grey volcanic sandstone. Most of this unit is covered by vegetation and moraine but a minimum thickness of 400 metres can be estimated. The top of the unit contains abundant recessive clasts of carbonate.

Unit 2 is up to 170 metres thick, and consists mainly of black, reddish weathering argillite and dark grey or black, 2 to 10-centimetre layered limestone. The unit also contains minor interbedded, grey or greenish grey volcanic sandstone and siltstone. This unit extends to the south and is truncated by a northwest-trending fault which juxtaposes Unit 3 and Unit 1.

Unit 3, well exposed on the ridge west of the Kliyul Creek, consists of grey or greenish grey volcanic sandstone and siltstone interbedded with dark grey or black limestone and minor black argillite, and is up to 440 metres thick. The lower part is dominated by greenish grey volcanic siltstone which contains abundant fragments of dark grey or purplish, well-bedded limestone, ranging from several centimetres to several metres in diameter. The upper part is greenish grey or pale grey, medium-layered (10 to 20 cm) volcanic sandstone interbedded with dark grey or black, thin-layered limestone or argillite. These limestone beds are very widespread and are useful marker horizons in the region. At the top of the unit there is a thin-layered, fine-grained volcanic sandstone, which is the boundary between Units 3 and 4.

Unit 4 consists mainly of massive, greenish grey volcanic sandstone and breccia with minor siltstone and clinopyroxene porphyry and is well exposed in the western part of the region. Rocks of this unit are very resistant and commonly form high peaks and steep cliffs. In the west, near the Dortatelle fault (Monger, 1977), these rocks are sheared into protomylonite. Lineations defined by stretched mineral crystals and elongated breccia fragments are very common. Because of the intense shearing, the total thickness of the unit cannot be measured, but a minimum thickness of 600 metres is estimated.

The stratigraphic succession in the Osilinka Ranges, east of Johanson Lake (Figure 1-12-1), appears similar to that in the northwest, but exact correlations between them have not proved possible.

The Goldway Peak and Dortatelle Peak area (Figure 1-12-1), in the southwest, has a stratigraphic succession very different from that east of the Dortatelle fault. It is dominated by volcanics and volcaniclastics and can be divided into two parts. The lower part consists of greenish grey, thin-layered volcanic sandstone interbedded with pale grey, thin-layered volcanic sandstone and siltstone, commonly with individual bed thickness less than 2 centimetres. Nonvolcanic sedimentary rocks are rare, but are observed near the glacier southeast of Goldway Peak and on the eastern flank of Dortatelle Peak where there are small amounts of thin-bedded (2 cm) dark grey or black limestone and argillite. The upper part consists of massive or poorly bedded, greenish grey volcanic sandstone and breccia with minor clinopyroxene porphyry. The breccias are polymictic and made up of predominantly subrounded fragments of volcanic sandstone and clinopyroxene porphyry. Thickness of this succession has not been measured but a minimum thickness of 2000 metres can be estimated (Figure 1-12-2c).

INTRUSIVE ROCKS

The upper Triassic Takla Group rocks are intruded by the Johanson Lake mafic-ultramafic complex, an Alaskan-type intrusive complex (Nixon and Hammack, 1990), the Darb Lake dioritic body which is located in the centre of the map area, and many intermediate to felsic dikes and sills, typically less than 3 metres wide. These intermediate to felsic rocks are probably related to the Hogem batholith and Jurassic to Cretaceous in age (Monger, 1977).

DEFORMATION

Rocks in the map area experienced deformation predominantly, and perhaps exclusively, associated with the dextral, transpressive displacement along the Finlay-Ingenika fault. This deformation is characterized by dextral strike-slip faults trending northwest, north-northwest and north-northeast, and sinistral strike-slip faults trending east-northeast. The faults cut the rocks into a number of fault-bounded, weakly deformed blocks, in which cleavages and small-scale shear zones are the only visible structures. These characteristics are typical of continental crustal deformation associated with large-scale transcurrent faulting (*e.g.* Nelson and Jones, 1986; Geissman *et al.*, 1989). There are also some large-scale, open to medium folds with axes trending northwest.

FOLDS

Two large-scale folds, an anticline and a syncline, have been recognized. The Wrede Range anticline, in the northwestern region of the map area, has Unit 1 volcanics and volcaniclastics in its core and Unit 2 volcaniclastic and interbedded sedimentary rocks on the two limbs. Bedding attitudes measured in Unit 2 define a fold axis trending 325° and plunging 30°. Axial-surface cleavage is common on both limbs, especially in the Unit 2 argillitic beds. The anticline is truncated on both northeast and southwest sides by northwest-trending, dextral strike-slip faults.

The Goldway Peak syncline is exposed around Goldway Peak, in the southwestern region. The core of the syncline consists of the upper, massive volcanic breccia and sandstone and the limbs are dominated by the lower, well-bedded, thin-layered volcanic sandstone and siltstone. The fold-axis trends 340° and plunges 40°. On both limbs near the nose, secondary, outcrop-scale folds are well developed. They are either box-type or chevron folds. The east limb of the Goldway Peak syncline is truncated by a northwest-trending, dextral strike-slip fault and the strata have been rotated clockwise through about 30° due to drag on the fault.

In contrast, the west limb was sheared by north-northwest-trending dextral strike-slip faults, which are parallel to the bedding surface, leading to steep dips for the strata.

Small-scale folds are also common in the well-bedded, thin-layered units throughout the map area, especially in the Unit 3 thin-layered limestone interbedded with volcanic siltstone west of Kliyul Creek. Most folds have axial surfaces at small (<45°) angles to the bedding surfaces and are probably due to bedding-parallel slip.

Timing of formation of the folds is uncertain. They predate the faults but may well have formed in the early stages of the dextral transpression (*cf.* Wilcox *et al.*, 1973; Sylvester, 1988).

FAULTS

Steeply dipping or vertical strike-slip faults are the most significant structural features in the map area. The faults may be divided into northwest, north-northwest, north-northeast and east-northeast-trending structures, which show different slip senses.

Northwest-trending faults are predominantly dextral and occur mainly in the Wrede Range and west of Kliyul Creek. In the Wrede Range, two northwest-trending faults cut the northeastern limb of the Wrede Range anticline and bring reddish sedimentary rocks of Unit 3 into contact with volcanic rocks of Units 1 and 4. These faults are well exposed to the northwest, where the volcanic rocks are sheared into protomylonite over a zone 20 metres wide. Drag folds and Riedel shears (Tchalenko, 1970; Sylvester, 1988) in the fault zone indicate dextral slip. By matching the offsets, a dextral displacement of 1 kilometre has been estimated along the faults. Some faults provide evidence of an early stage of dip-slip motion. For example, two sets of slickenlines are observed on the cleaved rock surfaces in a fault zone on Darb Creek near the Dortatelle fault. The earlier is dip-slip with a thrust sense, and the later is horizontal, dextral. These faults may originally have been thrust faults that were associated with the initiation of dextral displacement on the Finlay-Ingenika fault in the Ingenika valley west of the map area (*cf.* Sylvester, 1988).

North-northwest-trending faults are predominant in the southern part of the map area, and all show dextral displacement. The biggest and most obvious one is the Dortatelle fault. It extends 30 kilometres from north of Johanson Lake through Darb Creek to the south and is well exposed near the biggest lake north of Dortatelle Creek. Rocks in a fault zone 40 metres wide were sheared into protomylonite. In the mylonitic rocks kinematic indicators such as mylonitic foliation fish and S-C fabrics (Berthe *et al.*, 1979) are common (Plate 1-12-1c). Centimetre-scale drag folds, plunging steeply north-northwest, with axial planes striking northwest and dipping steeply northeast, are widespread. All the kinematic indicators are consistent with dextral strike-slip on the fault. To the south the fault passes through a col in which the volcanic rocks are mylonitic over a zone 50 metres wide. A fault-parallel, horizontal mineral-stretching lineation is very well developed, especially in the sheared clinopyroxene porphyry. A similar lineation is defined elsewhere by elongated fragments of volcanic breccia (Plate 1-12-1b). In a fault east of the Darb Creek dioritic body, a quartz diorite dike is incorporated in the mylonitic zone, indicating that fault motion occurred after emplacement of the extensive dioritic plutons in the map area, *i.e.* during the Jurassic or later (Monger, 1977). Faults in this group are parallel to, and have the same slip senses as, the Finlay-Ingenika fault west of the map area. They are also better developed and more closely spaced approaching the major fault to the west. It is therefore inferred that they were formed as a result of the dextral transcurrent movement on the Finlay-Ingenika fault.

North-northeast-trending faults are not as common in the map area as those of the other two sets. This may be due to vegetation and moraine cover in north-northeast-trending valleys. Two large-scale, north-northeast trending faults were mapped on the ridges west of Darb Creek. They cut the lower part of the volcanic sandstone and are characterized by protomylonites, with a mineral-stretching lineation parallel to the fault strike. S-C structures in the mylonitic zone, which is up to 20 metres wide, indicate dextral movement. Another shear zone with the same trend was mapped on the ridge behind the glacier west of Kliyul Creek. The Unit 4 greenish clinopyroxene porphyry is sheared into a narrow (10 cm) mylonitic band, in which S-C structures show dextral slip. On the east wall there is a small rotational structure, characterized by a number of curved cleavage planes that project to the south and diverge towards and converge away from the shear zone (Plate 1-12-1d). They are approximately parallel to the mylonitic foliation and die out outside the shear zone. The rotational structure is therefore a local feature and was probably associated with dextral transpression. The attitudes and slip senses on this north-northeast trending fault set are consistent with their formation as Riedel shears (R) related to the main motion on the Finlay-Ingenika fault (*cf.* Tchalenko, 1970; Sylvester, 1988).

East-northeast-trending faults generally display sinistral displacement. Although faults of this group are not well developed, they were found at several places within the map area. One such fault lies in the valley west of Darb Creek and is inferred from stratigraphic relationships. A 750-metre sinistral displacement of the lower part of the thin-layered, greenish grey volcanic sandstone and pale grey volcanic siltstone unit is required to match stratigraphic offsets. Another fault, striking approximately east, was mapped within the Johanson Lake mafic-ultramafic block, west of Darb Creek. It is characterized by a mylonitic zone, about 1 metre wide, and the drag folds of mylonitic foliation show a sinistral strike-slip sense. Approaching the Dortatelle fault, this small fault, together with the fault-bounded block, has been rotated clockwise through 35°. Small east-northeast-trending shear zones are also present in the area. A mylonitic zone 40 centimetres wide, striking 055°, observed on the peak of the Osilinka Ranges in massive, greenish grey volcaniclastics, has S-C fabrics indicative of sinistral displacement. The east-northeast-trending faults may be conjugate to the north-northeast-trending set, reflecting the R′ Riedel set (Tchalenko, 1970; Keller *et al.*, 1982; Sylvester,

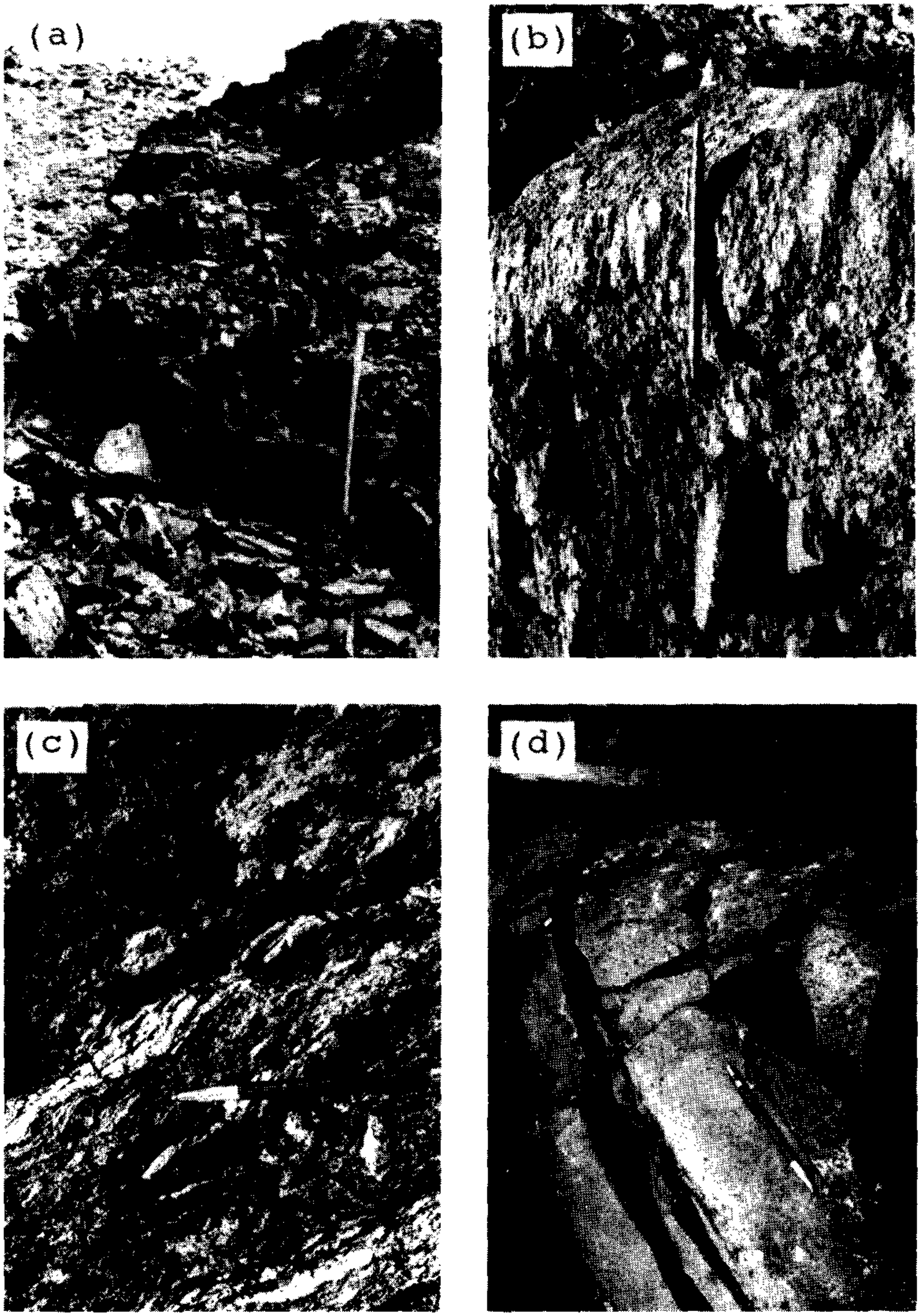

Plate 1-12 (a) Cleavage defined by closely spaced shear planes; (b) Lineation of stretched volcanic breccia in a north-northwest-trending, strike-slip fault; pencil parallel to the lineation, looking at north-northwest down; (c) S-C fabrics of the mylonitic rocks in Dortatelle fault, pencil parallel to the C planes, looking at south down; (d) Transpressive rotational structure consisting of curved cleavage planes; pencil parallel to the cleavage planes, hammer handle parallel to the small shear zone, looking at west down.

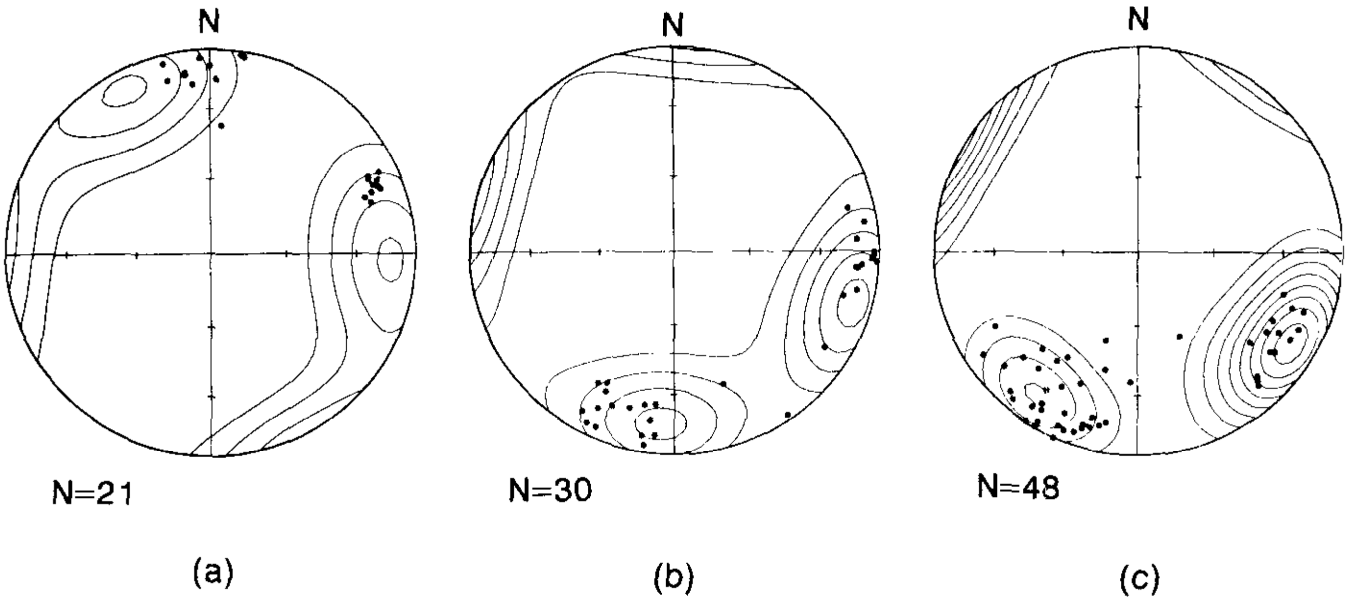

Figure 1-12-3. Stereonet plots of conjugate cleavages from the ridge north of Croydon Creek (a) the southern margin of Darb Creek dioritic body (b) and Goldway Peak (c). Solid circles: slickenlines; lines: contours of poles to the cleavages; N: number of cleavage planes measured.

1988) associated with faulting on the Finlay-Ingenika system.

All the faults, although they trend differently and have different slip senses, may be explained by association with the Finlay-Ingenika faulting. They cut the rocks into fault-bounded, weakly deformed blocks, ranging in size from several square kilometres to tens of square kilometres. With progressive displacement on the Finlay-Ingenika fault, deformation was apparently concentrated in the previously formed faults, while the fault-bounded blocks remained only very weakly deformed. Typically the only visible deformation outside the fault zones themselves is a cleavage and weak shear zones.

CLEAVAGE

Cleavage is extensively developed in the map area. It is characterized by spaced shear planes and in the cleaved rocks no appearent fabrics have been found. The shear planes are usually steeply dipping and closely spaced, at intervals of 2 to 10 centimetres (Plate 1-12-1a). They are commonly slickensides with slickenlines, and many are characterized by crystals of tremolite or patches of chlorite and epidote. Shear senses are evident from the slickenline steps and offset of such features as quartz veins or the conjugate cleavage. Most cleavage is regional but some is local in its distribution. The local cleavage is commonly associated with nearby faults and can be easily distinguished from the regional by tracing away from the fault. Regionally distributed cleavage generally occurs in conjugate sets trending north to north-northeast and east-northeast to east, although there is considerable variation. Assuming the regional cleavage was homogeneously distributed before the widespread faulting in this region, its attitudes may be used to indicate the bulk rotation of fault-bounded blocks.

Several hundred shear planes were measured in the field, and a preliminary analysis (Figure 1-12-3) indicates significant variations between the three major fault blocks. On the ridge north of Croydon Creek two sets of conjugate cleavages trend north and east-northeast, respectively (Figure 1-12-3a), which are consistent with those caused by Finlay-Ingenika faulting. To the west, in the block near the southern margin of the Darb Creek dioritic body, they trend north-northeast and east, respectively (Figure 1-12-3b). Near the Finlay-Ingenika fault at Goldway Peak, they are oriented northeast and east-southeast, respectively (Figure 1-12-3c). Based on the above assumption, this variation of the orientations of the regional, conjugate cleavages indicates that the fault-bounded blocks have been rotated clockwise, and the amount of block rotation varies, reaching a maximum close to the Finlay-Ingenika fault.

CONCLUSIONS

The deformation observed in the Takla Group rocks east of the Finlay-Ingenika fault can therefore all be explained by dextral transcurrent motions on the Finlay-Ingenika fault. There is no compelling evidence for deformation associated with the collision of Quesnellia with Stikinia or of Terrane 1 with North America. During the early stages of deformation, folds with axes trending northwest, northwest-trending thrust faults and two sets of conjugate strike-slip faults, striking north-northeast and east-northeast, were formed, together with north-northwest-trending, secondary dextral strike-slip faults. These structures cut the Takla Group rocks into a number of fault-bounded, weakly deformed blocks. With progressive displacement on the

Finlay-Ingenika fault, deformation became concentrated in early-formed fault zones. The northwest-trending thrust faults may have been rotated and dextral strike-slip motion appears to have been superimposed on them. The fault-bounded, brittle, upper crustal blocks appear to have been rotated clockwise in response to the large amount of dextral transcurrent displacement, the amount of rotation increasing toward the major faults. This rotation of discrete blocks is a mode of deformation common at shallow crustal levels in many strike-slip zones (Nelson and Jones, 1986; Ron *et al.*, 1986; Hudson and Geissman, 1987; Geissman *et al.*, 1989) and may provide one means of rationalizing the disparities between estimates of the amount of tectonic displacement derived from geological and paleomagnetic studies (Monger and Irving, 1980; Irving *et al.*, 1985; Rees *et al.*, 1985; Gabrielse, 1985).

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