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LEGEND

DESCRIPTIVE NOTES

Introduction

The geology of the map-area was compiled from maps spanning 70 years published at scales of 1:250 000 to 1:10 000. Concepts that influenced interpretation of field data evolved considerably over that time. Integration of the diverse maps was challenging; not all elements were resolved. Hindering better understanding of the geological evolution is the paucity of age information. Despite much modern geochronological work and a continuing search for rare paleontological samples, most of the many rock units in the area remain undated, their ages inferred by tenuous lithologic correlations and many tectonomagmatic events are similarly poorly dated. This compilation was undertaken in support of a regional study of groundwater resources and is therefore limited to the Okanagan River watershed.

In Canada, the watershed extends north from the 49th parallel for 180 km along the western margin of the Omineca Crystalline Belt, and east-west 100 km at its widest part. The nature of the geology changes markedly at Vernon across a structurally complex zone that extends northwest and east from the town.

North of the zone are low (to the west) and high (to the east) grade strata which can be correlated with somewhat better-dated rocks ranging in age from Neoproterozoic to Carboniferous found on the eastern flanks of the Shuswap Metamorphic Complex (SMC) that are considered to be stratigraphically linked to pericratonic successions of North America. High grade equivalents of these strata and their Mesoproterozoic basement comprise the SMC.

South of the zone are low and high grade strata of Ordovician to Permian ages that differ from coeval North American successions and that have been interpreted as parts of a suspect terrane. They contain evidence of Permo-Triassic deformation and erosion (Read and Okulitch, 1977), absent from the pericratonic succession, are unconformably overlain by Upper Triassic strata and are intruded by numerous plutonic rocks of Triassic to Paleogene ages. Older granitoid units may have formed a basement to the Paleozoic strata. Most of the high grade rocks may be correlatives of the low grade strata and plutons but their ages are poorly defined. Within leucosome sheets possibly extracted from adjacent para- and orthogneiss units by anatexis, a few zircons contain cores of Paleozoic and, rarely, Paleoproterozoic, ages (Parkinson, 1985; Brown, 2010). Most are distinct from any detrital or magmatic zircons encountered in North American pericratonic successions. The low grade assemblage is presently designated Quesnel Terrane and its presumed high grade equivalents largely east of the Okanagan Valley have been called the Okanagan Metamorphic and Plutonic Complex (OMPC) to distinguish it from the SMC (Okulitch, 1984). If the low and high grade rocks are all part of Quesnel Terrane, then the suture between North America and Quesnel Terrane is delineated by the belt of Carboniferous to Triassic strata within the structurally complex zone that passes through Vernon. This represents the approximate edge of North America prior to the Mesozoic and is the southwestern edge of a major salient of the craton that extends to just west of Shuswap Lake and passes eastward to the Kootenay Arc, a belt of polydeformed Neoproterozoic to Early Mesozoic strata. The craton does not appear to extend west from the southern part of the Arc (Acton, et al., 2002), as is conventionally assumed (e.g. Armstrong, et al., 1977; 1991), except perhaps in attenuated form and may only be exposed in culminations such as the Grand Forks Complex (Preto, 1970; Ross and Parrish, 1991).

The complex zone poses one of the major challenges to understanding of the geological evolution of the region. Its interpretation is linked to interpretations of a prominent regional marker unit, the Chase Quartzite (Thompson, et al., 2002).

The Chase Quartzite

Calcareous, diopsidic quartzite of the Chase Formation (Jones, 1959) has its type locality near the town of Chase on the Trans-Canada Highway. This distinctive lithology occurs sporadically in thin layers to thick pods within schist units of the Silver Creek Formation throughout the Vernon map-area (Okulitch, 1979) and to the east in the Kootenay Arc east of the Shuswap Metamorphic Complex (Thompson, et al., 2002; Lemieux, et al., 2007) and the formation name has been extended to all these widespread and discontinuous exposures. In most exposures, the compositional layering of the quartzite is transposed and contacts with various schist units are planar and presumably preserve little evidence of their original nature - depositional or tectonic. Despite seemingly consistent relationships with schist units structurally above and below the quartzite, these units vary in composition from place to place and similar lithological variants occur above and below the quartzite pods. Isoclinal, refolded folds are common throughout the structural stack and it may be that only a transposed pseudo-stratigraphy is present.

Sparse detrital zircon analyses indicate that the quartzite near the type locality cannot be older than earliest Devonian, (R.I. Thompson, pers. comm., in Glombick, 2005) and it can be inferred (Okulitch, 1985) to have been intruded by a polyphase foliated granitoid whose oldest known component is Late Devonian (R. Friedman, pers. comm., 2004; S. Brown, pers. comm., 2011).

In the Kootenay Arc (Lemieux, et al., 2007), the quartzite lies beneath the Carboniferous Milford Group and the youngest detrital zircon is earliest Devonian in age (but with uncertainties ranging from Ordovician to Late Devonian). Zircon ages show affinities with North American cratonal sources, pericratonal basins and volcanic arcs and but some may be reworked from Proterozoic strata. Zircons of early Paleozoic age (Roback, et al., 1994; Lemieux, et al., 2007) have no counterparts in the pericratonic succession to the east.

Calcareous quartzite virtually indistinguishable from the Chase Formation occurs south of Vernon in a west-trending band east of Kalamalka Lake (see description in the preceding section). Associated lithologies (Solberg, 1976 and Glombick, 2005) are predominantly amphibolitic paragneiss and schist in contrast to the Silver Creek Formation noted above. This occurrence, in addition to another well to the southeast of Deer Lake (Glombick, 2005) lie within the Okanagan Metamorphic and Plutonic Complex whose protoliths, largely undated, are postulated to be correlatives of late Paleozoic oceanic and arc-related allochthonous units of Quesnel Terrane.

The current working hypothesis embodied in this compilation is that the calcareous quartzite marks the locus of a broad belt of pericratonic North American and allochthonous Quesnel Terrane rocks tectonically interdigitated during the Permo-Triassic. The collision zone was then unconformably overlain by Upper Triassic marginal basin strata (Unterschutz, et al., 2002) and overprinted by Early Jurassic to Late Cretaceous deformation and magmatism. This was followed by Eocene extension that resulted in prominent detachment faulting predominantly (but not entirely) south of the zone and subordinate detachment faulting over-printed by normal faulting within and north of the zone..

Okanagan Valley Faults

The Okanagan Valley and adjacent valley walls contain a complex array of low and high angle faults, many with approximately northerly trends, although a significant number trend from northwest to northeast and a few extend east-west across the valley. On numerous maps, the largest of these have been inferred to extend under the very deep valley fill. Excluding the fill, the relief between the valley and nearby mountains exceeds that of the Grand Canyon of the Colorado River and this chasm is considered by some to be a major part of the catastrophic drainage that formed the Channelled Scablands of Washington (Shaw, et al., 1999). The valley fault system has been interpreted as either steep normal or gently west-dipping.

The presence of a west-dipping detachment has been debated since the initial proposal by Tempelman Kluit and Parkinson (1986). Models of a single, relatively planar detachment that extended from south of the US border to north of Shuswap Lake (e.g. Parrish, et al., 1988) were temporarily abandoned when detailed field evidence failed to substantiate the presence of detachment faults along significant portions of the valley, and such studies resulted in rejection of any detachment, preference being given to an array of normal faults (Thompson and Daughtry, 1996). Subsequent, more detailed mapping integrated with earlier data revealed a complex fault system of normal and detachment faults (e.g. Parkinson, 1985; Johnson, 1989; Bardoux, 1993; Glombick, 2005). Detachment faults can be found both west and east of the valley and within the watershed, only the central part near Penticton lies beneath Okanagan Lake.

From south to north, the evidence for detachment faulting is variably exposed. The detachment fault is visible immediately south of the border (Kruckenberg, et al., 2008). From the border to Oliver, the structure is concealed in the valley and is inferred from the juxtaposition of high grade poly-deformed strata and plutons with Eocene cooling ages to the east and low grade poly-deformed strata and massive plutons with Mesozoic cooling ages to the west.

Between Oliver and the south end of Skaha Lake, the detachment was delineated by Parkinson (1985) and passes from the east side of the valley to well to the west of it where spectacular Eocene mega-breccias were formed coeval with movement. Classic development of mylonitic fabric passing upwards into a chlorite breccia zone unequivocally support an interpretation of detachment faulting possibly before, during, and after eruption of Eocene volcanic rocks (McClaughry and Gaylord, 2005). The zone of high strain is thick along this portion of the detachment and was mapped by Christie (1973) well to the east of the valley, with discrete zones of greater deformation at several structural levels. Some of the mapped structures may be of Mesozoic age if pre-mylonite polyphase folds are preserved between the high strain zones. Later normal faults have displaced the detachment near the south end of Skaha Lake (Brown, 2010). Similar mesoscopic faults are common throughout the mylonite zone within the watershed region.

The large gap in detailed information on the east side of the valley that extends along Skaha Lake to well north of Penticton has been filled in part and supported by geochronological analysis (Brown, 2010) but commonly the presence of the detachment can only be inferred by the close proximity of high grade and very low grade rocks. Outliers of the detachment are now known to occur well to the east of the valley. Detailed mapping and geochronological studies cover the east side of the valley within the bend of the lake (Medford, 1976) and north to Kelowna (Bardoux, 1993). The age of the mylonitic fabric is constrained by a foliated granodiorite (U-Pb, 68 Ma and K-Ar 49 Ma; Geological Survey of Canada, internal report, 1979) and by K-Ar and numerous fission track cooling dates (Medford, 1976) and U-Pb crystallization ages of syn-tectonic intrusions (Brown, 2010) ca. 50 Ma. As in Parkinson's study area near Oliver, the classic progression from mylonite, through fractured chloritic mylonite, to thick chlorite breccia is well exposed east of Kelowna along Highway 33 below Black Knight Mountain and throughout the area mapped by Bardoux (1993). Eocene strata are faulted and tilted into the gently west-dipping plane of the mylonitic foliation. At this latitude, the main detachment extends far to the east of the valley and Bardoux (1993) indicated that it, or other detachments, appear to be broadly folded surfaces with easterly as well as westerly dips and such a geometry may be typical of much of the detachment to the north and south (Brown, 2010). The large re-entrants in the plan view of the detachment(s) may be explained by such warping.

North of Kelowna, the detachment is not well exposed and is partially covered by Miocene plateau basalts. In the Wood/Kalamalka lakes area, Glombick (2005) mapped what appeared to be two east-west normal faults that displaced the detachment, however, available outcrop permits an alternate interpretation, shown in this compilation, of a detachment folded about east-northeast axes. Where structural data permit, approximate axial traces of major antiforms and synforms are indicated. Similar corrugations of the detachment surface have been mapped by Brown (2010). North of this locality, most of the detachment zone lies almost entirely under Kalamalka Lake but mylonite fabrics are present along the east side of the lake, their intensity diminishing eastward as illustrated by their effects on the east-west trending calcareous quartzite unit at Cosens Bay. Imposition of mylonitization in this area did not result in significant dismemberment of the steeply dipping quartzite (except, perhaps, under the lake).

The area between Kalamalka Lake and Vernon contains the northern limit of reasonably well-documented Eocene detachment faulting in the Okanagan Valley. What has been interpreted as a west-side-down normal fault (Thompson and Unterschutz, 2004; Glombick et al., 2004) extends to the north. High grade rocks are juxtaposed against low grade and gently-dipping mylonite fabrics occur at several levels on the east side of the valley. Although there is no reason to suppose a major structure such as described to the south should end abruptly, neither is there clear documentation of its geometry in this area, nor are the ages of the various mylonite zones known. It is reasonable to suppose that the amount of displacement decreases northward and the low angle fault(s) rise to become steep breakaway zones, however connections to the Eagle River Detachment just north of the watershed (Johnson, 1989; 2006) have been proposed.

Much remains to be understood about the evolution of rocks adjacent to the detachment. In the SMC and OMPC one or more episodes of deformation and metamorphism predate Eocene faulting and the ages of many of these events and the protoliths are unknown. In low grade rocks deformation occurred from the Permo-Triassic to Paleogene. Transitions between low and high grade rocks occur east and west of the valley; some are abrupt and clearly faulted. However, if pre-detachment deformation juxtaposed rocks at a variety of metamorphic grades, both the infrastructure and suprastructure of the Eocene detachments, where they occur, locally may contain low and high grade rocks. Mylonite zones seem to occur at several structural levels and cannot all be assigned an Eocene age with confidence. In such areas, Eocene structures can only be defined by the distribution of Eocene cooling ages (e.g. Mathews, 1964). Several discontinuous detachment faults may die away northward into a zone of normal faults and/or descend into high grade rocks east of the valley. The complexity of detachment systems in this region has been well demonstrated by Johnson, (2006). Complex detachment faulting extends south of the international border (Kruckenberg, et al., 2008). Mylonite and brittle fault zones accompanied by extensive hydrothermal systems, formed before, during and after a prolonged episode of Eocene volcanism (see below).

Paleogene Volcansim

The distribution of Eocene volcanic and sedimentary rocks define a system of extensional basins and coalescing volcanic centres in the hanging wall of the detachment fault predominantly in the western half of the watershed (Church, 1978). Well constrained ages of eruption and deposition are sparse but magmatic activity appears to span the period of extensional faulting and exhumation of the high grade complex and may have persisted after most motion ceased. Relationships between the volcanic and sedimentary strata and high-level intrusive phases, and the high grade rocks to the east are therefore complex. The Eocene volcanic and sedimentary strata, and their Mesozoic and older basement, are highly dismembered by numerous high angle brittle faults above the shallow-dipping detachment.

Miocene and Pliocene basaltic flows (Church and Suesser, 1983; Mathews, 1988) cap both high and low grade terranes and Quaternary flows fill a valley west of Kelowna (Sluggett, 2008).

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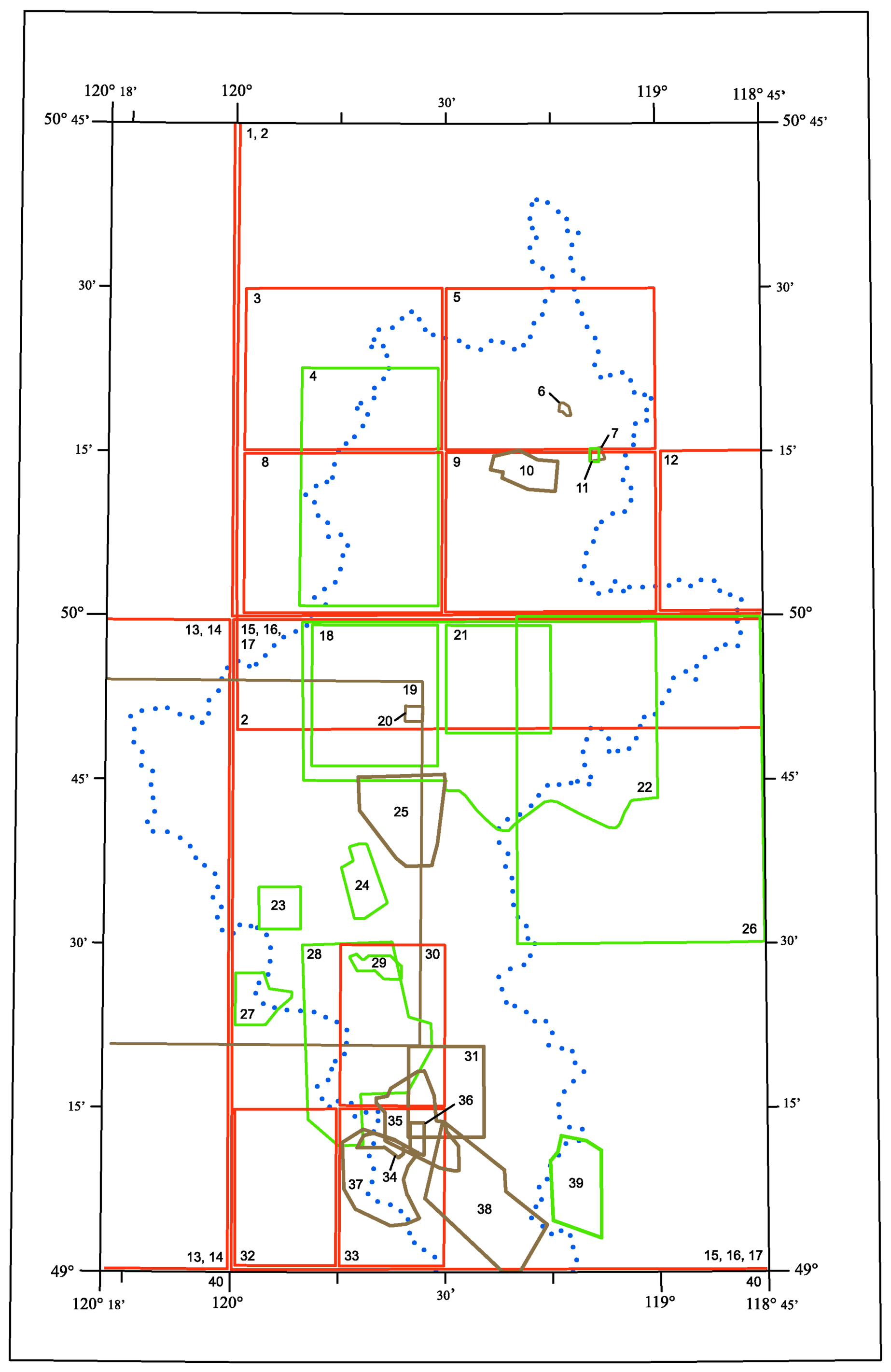
Sources of Information



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Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

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