Harzburgite Peak: A large mantle tectonite massif in ophiolite from southwest Yukon

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ABSTRACT

Detailed mapping of bedrock in the northern Wellesley basin adjacent to the Donjek River revealed a coherent sequence of cumulus-textured gabbros, sheeted dykes, and a large massif of spinel harzburgite. The coarse-textured harzburgite tectonite covers an area of ~75 km^2, and is generally well preserved, making it one of the largest and most exceptional mantle tectonite bodies yet recognized in Yukon. Together with regional aeromagnetic data the new field observations are interpreted as part of a large ophiolite complex with a strike length extending ~100 km throughout the Wellesley basin. No age data are available, but correlation with identical ultramafic bodies to the northwest in Alaska suggests that the ophiolite in Wellesley basin may represent a klippe of Slide Mountain Terrane overlying rocks of the Yukon-Tanana Terrane.

RÉSUMÉ

La cartographie détaillée du substratum rocheux dans le nord du bassin de Wellesley près de la rivière Donjek a révélé la présence de séquences cohérentes de gabbros à texture de cumulus, de dykes stratifiés, et un gros massif de harzburgite à spinelle. La tectonite de harzburgite à texture grossière couvre une superficie de ~75 km^2; elle est généralement bien conservée, ce qui en fait l'un des amas de tectonite mantellique les plus vastes et les plus exceptionnelles du Yukon. Conjuguées aux données aéromagnétiques régionales, les nouvelles observations de terrain en font un vaste complexe ophiolitique d'une longueur de ~100 km à travers le bassin de Wellesley. Malgré l'absence de datations, il est possible de le corréler avec des massifs ultramafiques identiques au nord-ouest en Alaska. Les ophiolites du bassin de Wellesley pourraient donc représenter une klippe du terrane de Slide Mountain reposant sur le terrane de Yukon-Tanana.

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INTRODUCTION

Ophiolites are integral parts of many mountain belts. Their study aids in understanding the assembly of orogens and the history of seafloor spreading in past ocean basins (Moores, 1982; Moores and Jackson, 1974). Ophiolites occur throughout the Cordillera, and have been the subject of many detailed studies in California and Oregon (see Coleman, 2000), but with fewer comprehensive studies to the north in Yukon and Alaska. This contribution describes detailed mapping of gabbros, sheeted dykes, and a large massif of harzburgite tectonite in the Wellesley basin of southwest Yukon, extending investigations from the previous year (Shellnutt et al., 2001).

STUDY AREA

The field area lies just north of Wellesley basin and straddles the Donjek River, 10 km east of its confluence with the White River in southwest Yukon (Fig. 1). The study area is accessed by helicopter from an abandoned airstrip near the village of Snag, the latter reached by a four wheel drive passable road north of the Alaska Highway. Wellesley basin is characterized by low-lying swampy areas giving way to largely vegetated peaks but with good bedrock exposure.

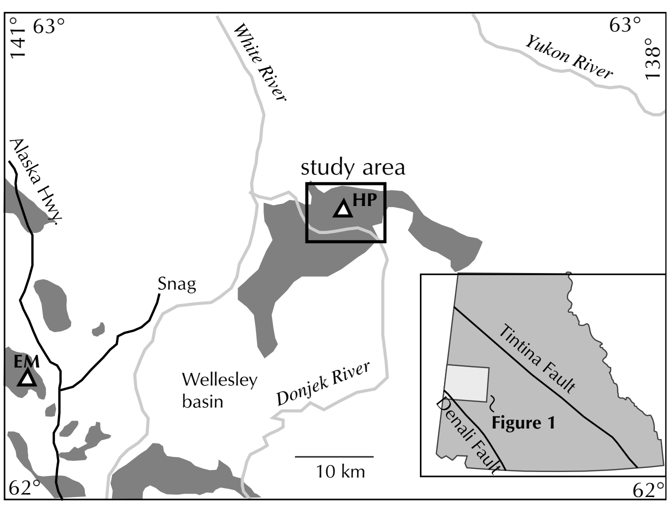


Figure 1. *Location of the study area in southwest Yukon, showing bedrock geology assigned to Windy-McKinley Terrane (shaded, Gordey and Makepeace, 1999). Also shown are the locations of Harzburgite Peak (HP) and Eikland Mountain (EM) referred to in the text.*

Rocks in the area were previously mapped at 1:250 000 scale by Tempelman-Kluit (1974) who recognized isolated bodies of gabbro, harzburgite and "massive and featureless greenstone." Tempelman-Kluit (1974) recognized a spatial association of mafic and ultramafic rocks in the area but his study, being reconnaissance in nature, did not recognize any distinct coherency or stratigraphic relationships between them. Tempelman-Kluit (1976) assigned these mafic and ultramafic rocks a probable Permian-Triassic age, on the basis of correlations to limestones bearing similar ages associated with similar rocks to the southeast near Atlin. This would place at least some of the mafic and ultramafic rocks in southwest Yukon as part of the Cache Creek Terrane (Monger, 1991). Limestones associated with similar mafic and ultramafic rocks, however, also occur to the northwest in Nabesna Quadrangle of Alaska, and contain coral and stromatoporoids of Devonian age (Richter, 1976). This correlation has served in part as the basis for assigning mafic and ultramafic rocks in Wellesley basin to the Windy-McKinley Terrane, an assemblage of early Paleozoic-Cretaceous mélange and gabbro with oceanic affinity (Monger, 1991).

GEOLOGY

In this study, detailed mapping revealed units of gabbronorite and gabbro, a small interval of sheeted dykes, and a large massif of harzburgite tectonite in a sequence southward from granitoids of the Dawson Range (Fig. 2).

GABBRO AND GABBRONORITE

Large and continuous exposures of gabbro and gabbronorite occur south of the contact with granitoids of the Dawson Range batholith. The rock is isotropic and medium- to coarse-grained. Grain size can be patchy and heterogeneous on a metre-scale. The rock contains euhedral plagioclase, with well developed cumulus textures in oikocrysts of ortho- and clinopyroxene. Clinopyroxene has two sets of exsolution lamellae forming a herringbone texture. Also notable are trellis-textured ilmenite and minor apatite. Plagioclase and clinopyroxene are fresh (Fig. 3a). Orthopyroxene has altered to serpentine and chlorite, with only relict cores preserved, that weather a conspicious rusty brown.

SHEETED DYKES

Dykes, 10 cm to 1 m wide, sporadically cross-cut gabbro, and increase in concentration southward to a point where they are difficult to distinguish from fine-grained gabbro or 'greenstone', except for having chilled margin contacts. The dykes are not well exposed or areally extensive. They are dark green on a fresh surface, aphanitic, rarely plagioclase-phyric, and commonly contain millimetre-sized veins and stringers of epidote, quartz and carbonate. In thin section the dykes show subophitic textures. Clinopyroxene is locally fresh, but is more commonly replaced by actinolite and chlorite. Plagioclase is only slightly altered to epidote and chlorite. Minor ilmenite shows skeletal textures and is replaced by leucoxene. Some of the dykes have a mesostasis of former glass, now replaced by chlorite (Fig. 3b). Conspicious blebs of pyrrhotite (<1 mm) are recognized in some dykes.

HARZBURGITE

A 75 km^2 mass of this rock forms Harzburgite Peak (Fig. 1). A second large mass occurs to the southeast, immediately across the Donjek River (Tempelman-Kluit, 1974). This rock is massive and weathers dun brown. Centimetre-scale layering defined by varying olivine/orthopyroxene ratio (Fig. 4a) is observed in places, but is not common throughout the area. Rare metre-long replacive dunite bodies (Kelemen and Dick, 1995) are concordant to layering but pinch out along strike. Olivine is recessive, whereas orthopyroxene (1–2 cm) and spinel (up to 5 mm) weather up to produce a knobby surface.

In thin section the rock is coarse-textured. Olivine (1 to 4 mm) is partially serpentinized, whereas orthopyroxene is fresh in most places, and shows exsolution lamellae of clinopyroxene and well developed kink-banding (Fig. 4b). Spinel occurs as either symplectitic intergrowths within orthopyroxene (Fig. 4c), or as holly-

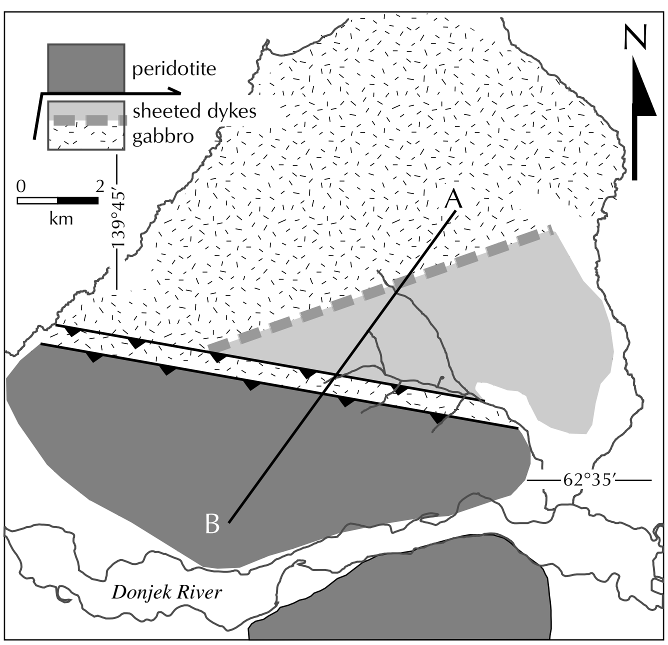


Figure 2. Simplified geological map of study area (location shown in Figure 1). Line A-B indicates the location of a cross-section shown in Figure 6. The gabbro-sheeted dykes contact, indicated by the dashed grey line, is gradational. Triangular teeth point into the hanging wall of thrust faults.

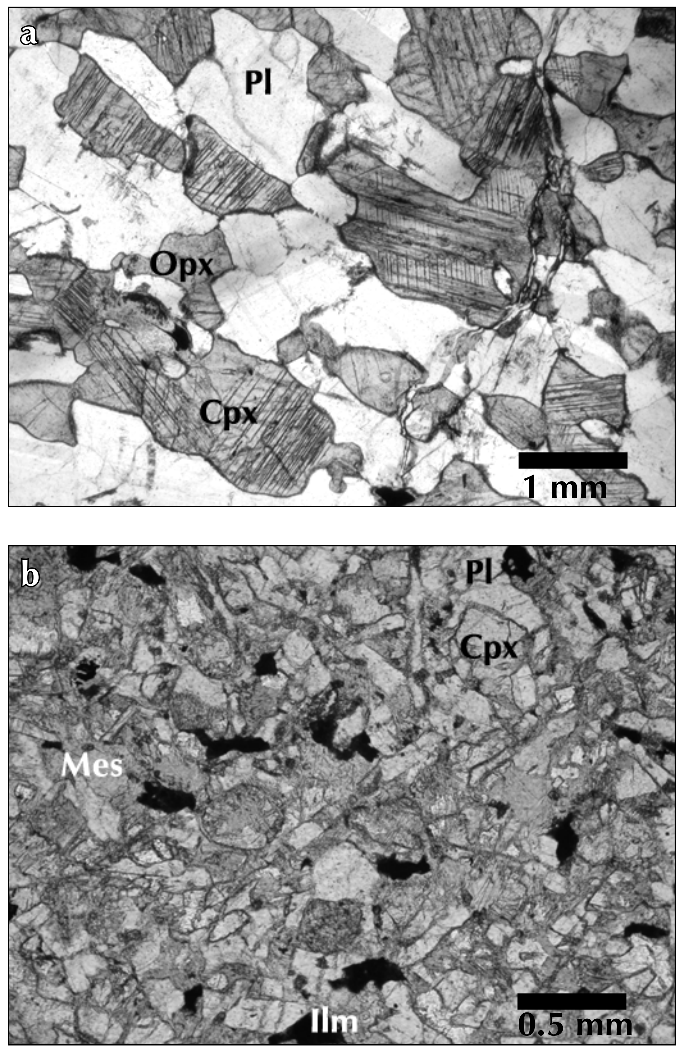
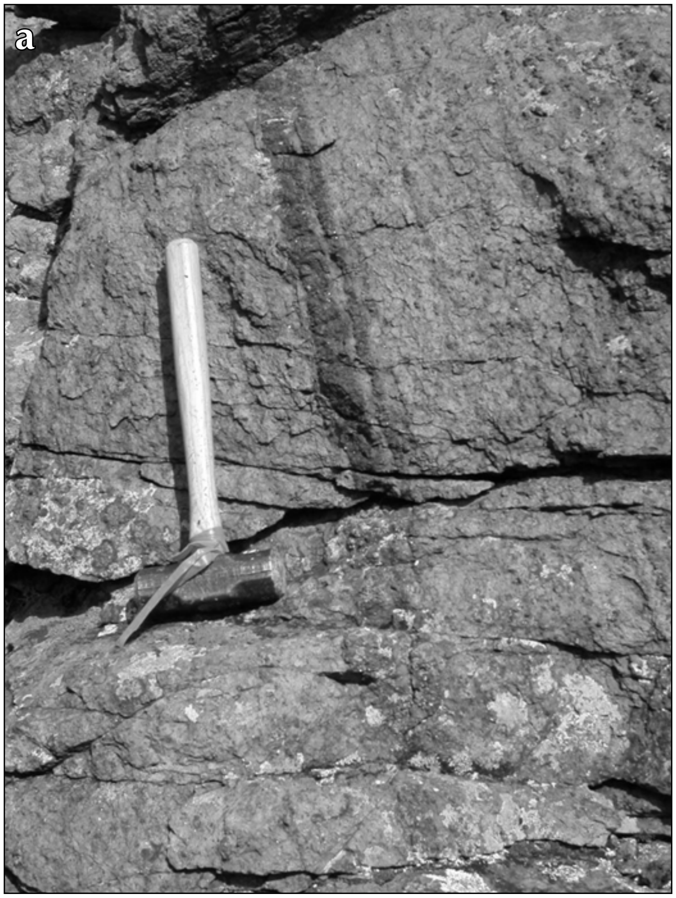
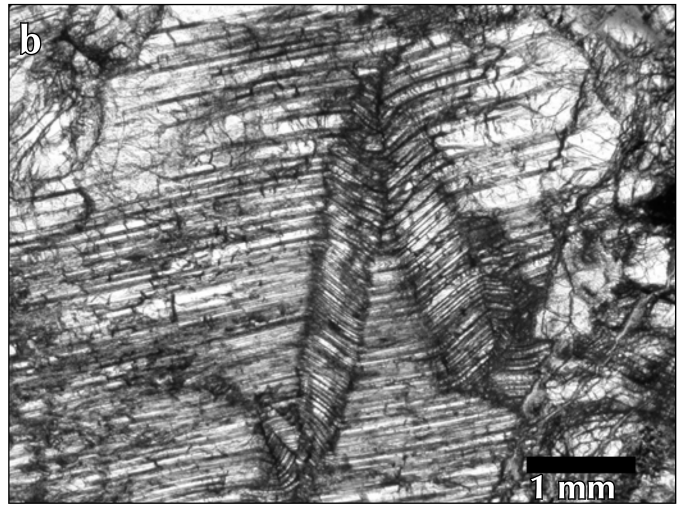


***Figure** 3.* *Petrographic observations of gabbro and sheeted dykes. **(a)** Photomicrograph in plane-polarized light of gabbro, showing plagioclase (Pl), clinopyroxene (Cpx) and orthopyroxene (Opx). **(b)** Photomicrograph in plane polarized light of sheeted dyke, showing plagioclase (Pl), clinopyroxene (Cpx), ilmenite (Ilm) and a mesostasis of chlorite after glass (Mes).*





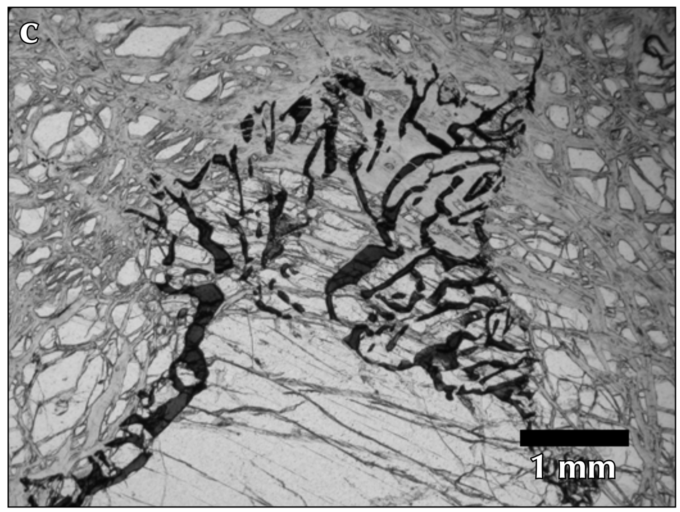


***Figure 4. (a)** Outcrop showing layering defined by varying olivine/orthopyroxene ratio in harzburgite body. Rock hammer for scale is 40 cm long. **(b)** Photomicrograph in plane-polarized light of orthopyroxene in harzburgite showing well developed kink-banding. **(c)** Spinel symplectite (dark) intergrown with orthopyroxene in harzburgite. Plane-polarized light.*

leaf textures typical of many mantle tectonites (Mercier and Nicolas, 1975). Clinopyroxene is rare, but where present occurs mainly along grain boundaries with orthopyroxene and spinel. The clinopyroxene content increases to the southwest in the harzburgite body. The degree of serpentinization is patchy on the outcrop scale and mainly concentrated along joint planes.

STRUCTURE

The gabbro and dykes show little internal strain. Primary fabrics and relationships, such as cross-cutting dykes with sharp straight contacts, are well preserved and unstrained. Primary layering (S_1) is evident in the peridotite body and is defined by parallel lensoidal orthopyroxene grains, by more resistant orthopyroxene-rich layers that stand out against the more easily weathered rock, and by recessive partings that appear to be more olivine-rich. Spinel lenticles and thin (<1 cm thick) orthopyroxene porphyroclasts define rare tight to isoclinal, rootless, intrafolial folds with axial surfaces that parallel the primary layering. The layering is better developed to the east. The primary layering defines a steeply east-dipping panel with an average orientation of 031°/58° (strike and dip, right-hand rule for this and subsequently reported orientations of planar structures; Fig. 5). Minor variations in orientation suggest folding about an east-plunging fold axis. The primary layering is interpreted as a record of ductile flow and shearing in the mantle (Nicolas, 1995; Nicolas and Violette, 1982). The tight to isoclinal, intrafolial folds, the presence of lensoidal orthopyroxene grains, and orthopyroxene-rich layering are all consistent with high-temperature ductile flow and recrystallization. These fabrics are commonly developed in mantle tectonites and are attributed to shearing of hot lithosphere (Dick and Sinton, 1979; Nicolas, 1995; Nicolas and Violette, 1982).

A spaced cleavage (S_2) is present throughout the harzburgite body and consists of regularly spaced fissile partings that preferentially weather out. Where closely spaced, the cleavage imparts a flaggy appearance to the rock. Locally, where the rock is well jointed and fissile, the cleavage is irregular and difficult to distinguish from the joint sets. The cleavage strikes parallel to the east-trending ridge that runs through Harzburgite Peak, and dips regularly to the south, with a mean orientation of 096°/71° (Fig. 5). The cleavage parallels the contact with the gabbro and sheeted dykes to the north.

Cleavage (S_2) and primary layering (S_1) intersect in a moderately east-southeast-plunging intersection lineation (L_2; Fig. 5). This east-southeast-plunging line is interpreted as the fold axis about which primary layering was folded. Cleavage is interpreted as being axial planar to these folds

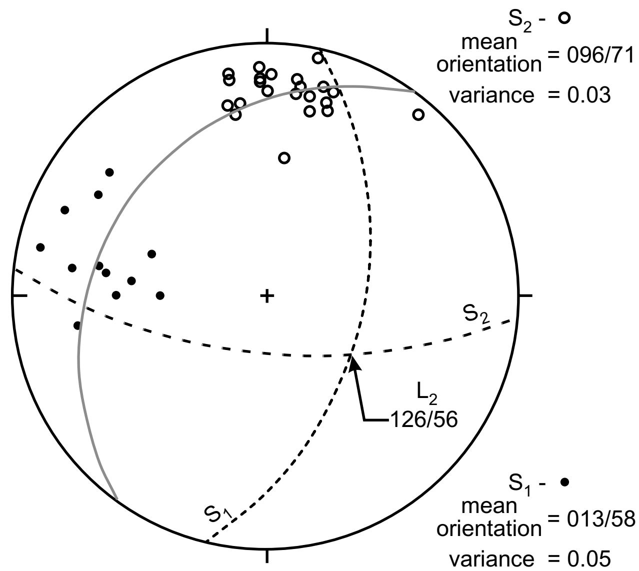


Figure 5. *Stereonet showing orientation data (poles to planar structures) for primary layering (S_1) and cleavage (S_2) in harzburgite tectonite. Mean orientations are given as strike and dip (right-hand rule) and shown as great circles on stereonet (S_1 – tightly dashed line; S_2 – spaced dashed line). The line of intersection (L_2) of S_1 and S_2, indicated by the arrow, is given as trend and plunge. The great circle shown in grey defines the plane perpendicular to the S_1 – S_2 intersection lineation and gives the orientation of the profile plane used in the construction of the cross-section A-B shown in Figure 6.*

and to have developed during F_2 folding. The east-southeast-plunge of F_2 implies that eastward tilting has exposed deeper crustal levels to the west, and shallower levels to the east. The construction of a down-plunge projection shows the geometry of the rock units in profile (Fig. 6).

In profile it is evident that the structurally deepest parts of the peridotite body are exposed to the west in the region characterized by increased clinopyroxene content, indicating presumably more fertile mantle. These observations are consistent with the peridotite body being a steeply tilted section of mantle that shallows upward to the east. Measured perpendicular to the primary layering, which defines an open synform, it is evident that the mantle section at Harzburgite Peak is more than 5 km thick. The preservation of downward-increasing clinopyroxene content and decreasing shear fabrics suggests that this is an intact sheet of mantle that has not been structurally imbricated.

The peridotite body structurally overlies the gabbro and sheeted dyke complex (Figs. 2, 6). The primary layering within the peridotite ends down against, and is truncated by, the contact. Cleavage in the peridotite body parallels the contact. These relationships indicate that folding of the peridotite and related cleavage development occurred

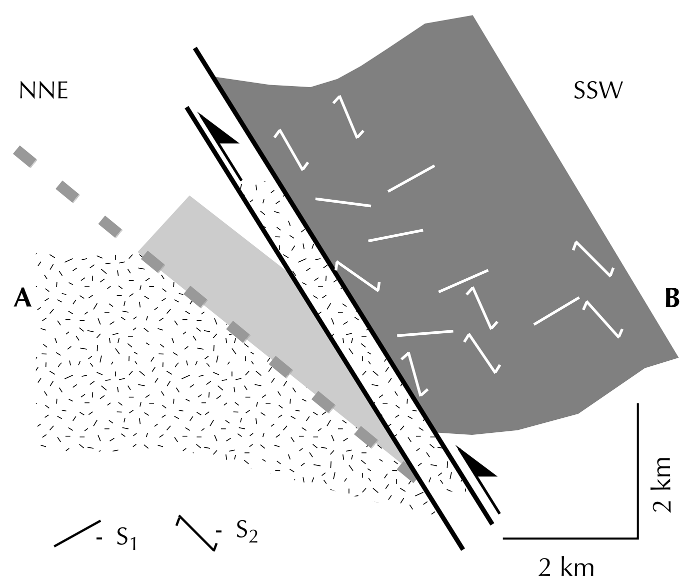


Figure 6. *Cross-section A-B, constructed by projecting surface data down-plunge using the technique described by Johnston (1999). Unit fills are as shown in Figure 2. Projected structural data in the peridotite include cleavage (S_2) and primary layering (S_1).*

in response to faulting of the peridotite body against the gabbro. The geometry of the fault, together with the juxtaposition of structurally deeper mantle in the hanging wall over top of shallower crustal gabbros and dykes in the footwall, suggests that the fault is a thrust fault. The fault cuts up-section through layering in the hanging wall toward the northeast, indicating that fault vergence was to the northeast. The steep orientation of the faults could indicate that they were rotated during movement over ramps in deeper seated thrust faults that would crop out further to the northeast.

DISCUSSION

The distinct spatial association of gabbro and harzburgite tectonite in the map area was recognized earlier by Tempelman-Kluit (1974). The recognition of sheeted dykes spatially associated with gabbro is new and significant for the overall regional interpretation of mafic and ultramafic rocks assigned to the Windy-McKinley Terrane in southwest Yukon. The sequence from north to south of gabbro, sheeted dykes and harzburgite tectonite is convincing evidence that these rocks belong to part of a coherent ophiolite. The location of sheeted dykes between harzburgite and gabbro is out of sequence, but is likely the result of fault imbrication. The mantle section has been thrust northward over the sheeted dykes, along a fault that parallels a foliation striking east-southeast in the harzburgite body (Fig. 6). The areal extent of the harzburgite body, its excellent state of preservation, and 5 km of structural thickness, make this one of the most exceptional mantle sections of ophiolite in Yukon.

Observations in the study area are difficult to extend to the immediate area of Wellesley basin due to poor exposure and only reconnaissance mapping. Regional aeromagnetic surveys of the area (Lowe et al., 1994) are particularly helpful in this regard, however, and coupled with a recent geological compilation (Gordey and Makepeace, 1999) reveal some regionally significant

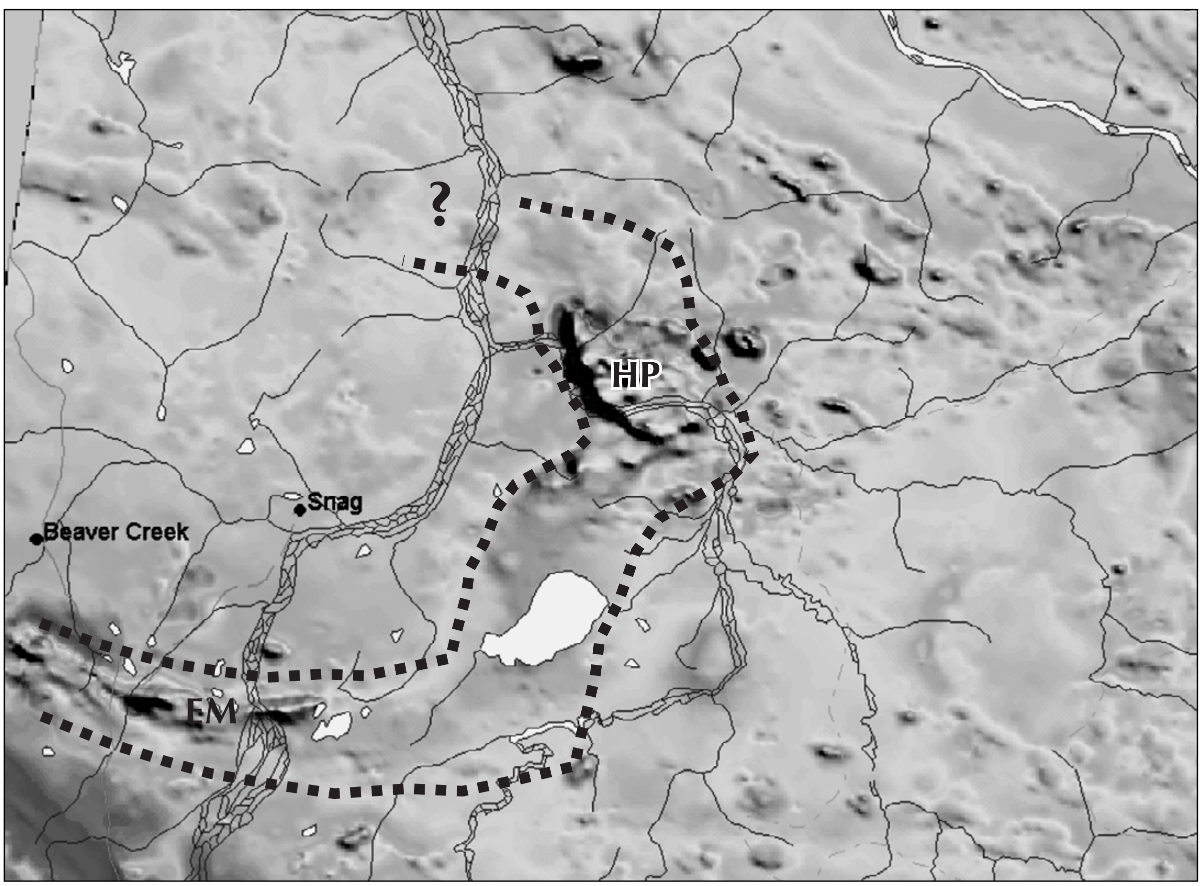


Figure 7. *Aeromagnetic image for southwest Yukon (Gordey and Makepeace, 1999; Lowe et al., 1994). Dashed lines outline an arcuate aeromagnetic anomaly traceable from the study area near Harzburgite Peak (HP) through Wellesley basin to Eikland Mountain (EM).*

correlations. The sequence of ophiolitic rocks observed in the study area surrounding Harzburgite Peak defines a strong magnetic anomaly (Fig. 7), the source of which is likely magnetite produced by serpentinization of the harzburgite. This magnetic anomaly can be traced from Harzburgite Peak along an arcuate pattern in the subsurface of Wellesley basin to Eikland Mountain (Fig. 1, 6), where a strong spatial association of gabbro, harzburgite and "greenstone grading into gabbro" was observed by Tempelman-Kluit (1974). The latter statement is re-interpreted here to represent sheeted dykes spatially associated with gabbro, as observed in this study north of Harzburgite Peak. The arcuate magnetic anomaly is interpreted to define a ~100-km-long ophiolite that constitutes an antiform, plunging gently southeast in a klippe thrust over crystalline rocks of the underlying Yukon-Tanana Terrane.

Unfortunately, there is no age control on mafic and ultramafic rocks in Wellesley basin. Previous work can accommodate many possibilities and interpretations. Mafic and ultramafic rocks in the study area were assigned Devonian ages, based on correlation of an unfossiliferous limestone in Wellesley basin with Devonian-aged corals and stromatoporoids in a limestone hundreds of kilometres away in adjoining Nabesna Quadrangle in Alaska (Richter, 1976). Rock types in the study area and described elsewhere in Wellesley basin, however, bear a remarkable geological and petrographical similarity to several tens of isolated occurrences of ultramafic rocks in the Yukon-Tanana Uplands and along the Salcha River to the northwest in Alaska (Foster and Keith, 1974; Keith et al., 1981; Patton et al., 1994; Shellnutt et al., 2001). The latter show strong and locally coherent associations of harzburgite tectonite with gabbro and greenstone, and show evidence for being overthrust on crystalline rocks of Yukon-Tanana Terrane (Foster et al., 1985).

Ultramafic rocks in the Yukon-Tanana Uplands and Salcha River area have Permian ages, based on fossiliferous limestone and chert associated with greenstones, and have been included in the Salcha-Seventy Mile Terrane, equivalent to Slide Mountain Terrane in Yukon (Foster et al., 1994; Patton et al., 1994). If the correlation is made between these rocks and the ophiolite sequence traceable throughout Wellesley basin, then the latter is likely part of Slide Mountain Terrane, and may be Permian rocks thrust over Yukon-Tanana Terrane, as originally inferred by Tempelman-Kluit (1976). If true, then these and similar rocks need not belong to Windy-McKinley Terrane, which on this basis may require revision and/or abandonment. Future work focusing on the geochronology of gabbro bodies in the study area could test this hypothesis.

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