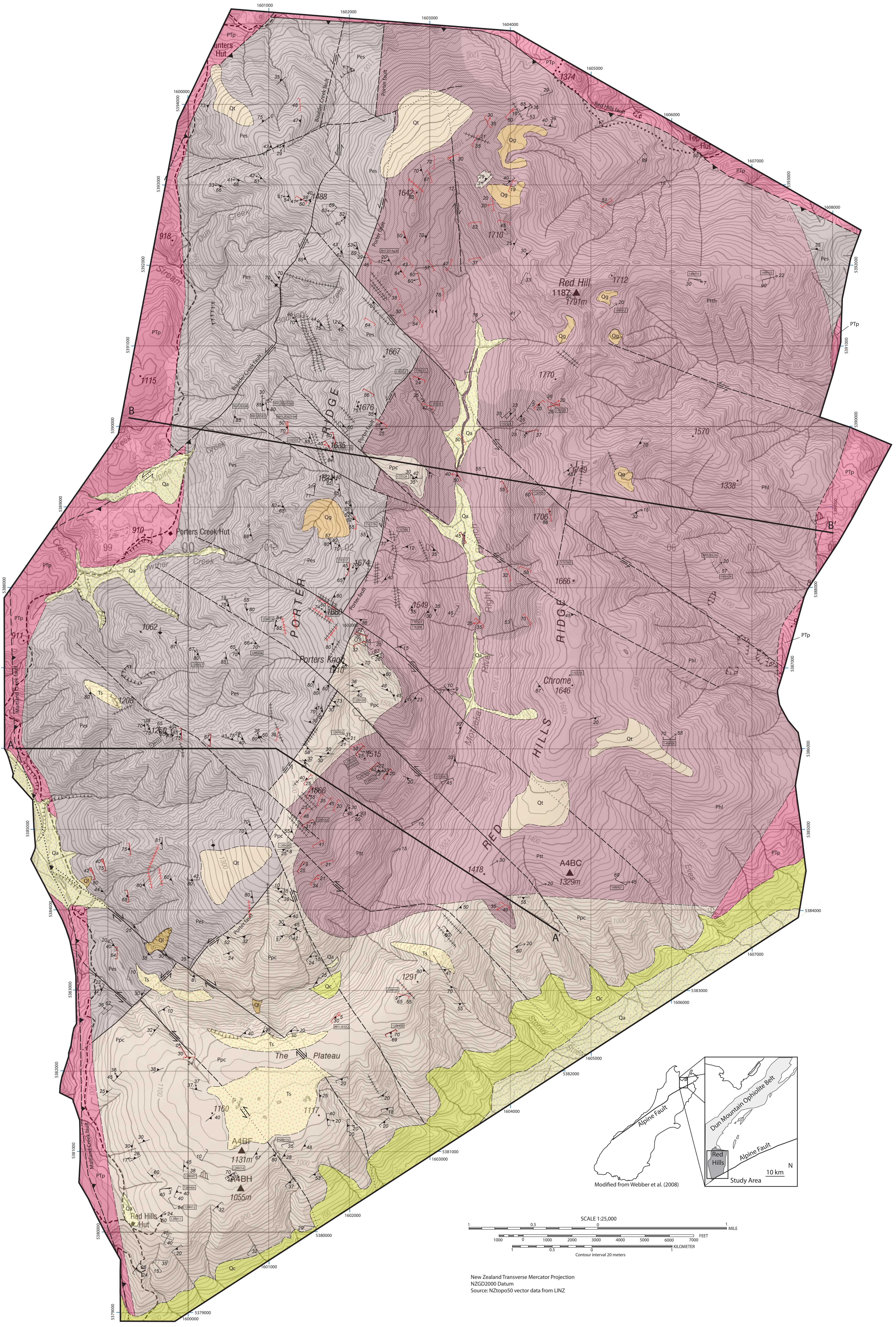
GEOLOGIC MAP OF THE RED HILLS ULTRAMAFIC MASSIF, MARLBOROUGH DISTRICT, SOUTH ISLAND, NEW ZEALAND

Eric D. Stewart, Virginia Toy, Basil Tikoff, Seth Kruckenberg, Julie Newman

2015



Alpine Fault

Dun Mountain Ophiolite Belt

Red Hills

Alpine Fault

N

10 km

Study Area

Modified from Webber et al. (2008)

SCALE 1:25,000

1 0.5 0 1 MILE

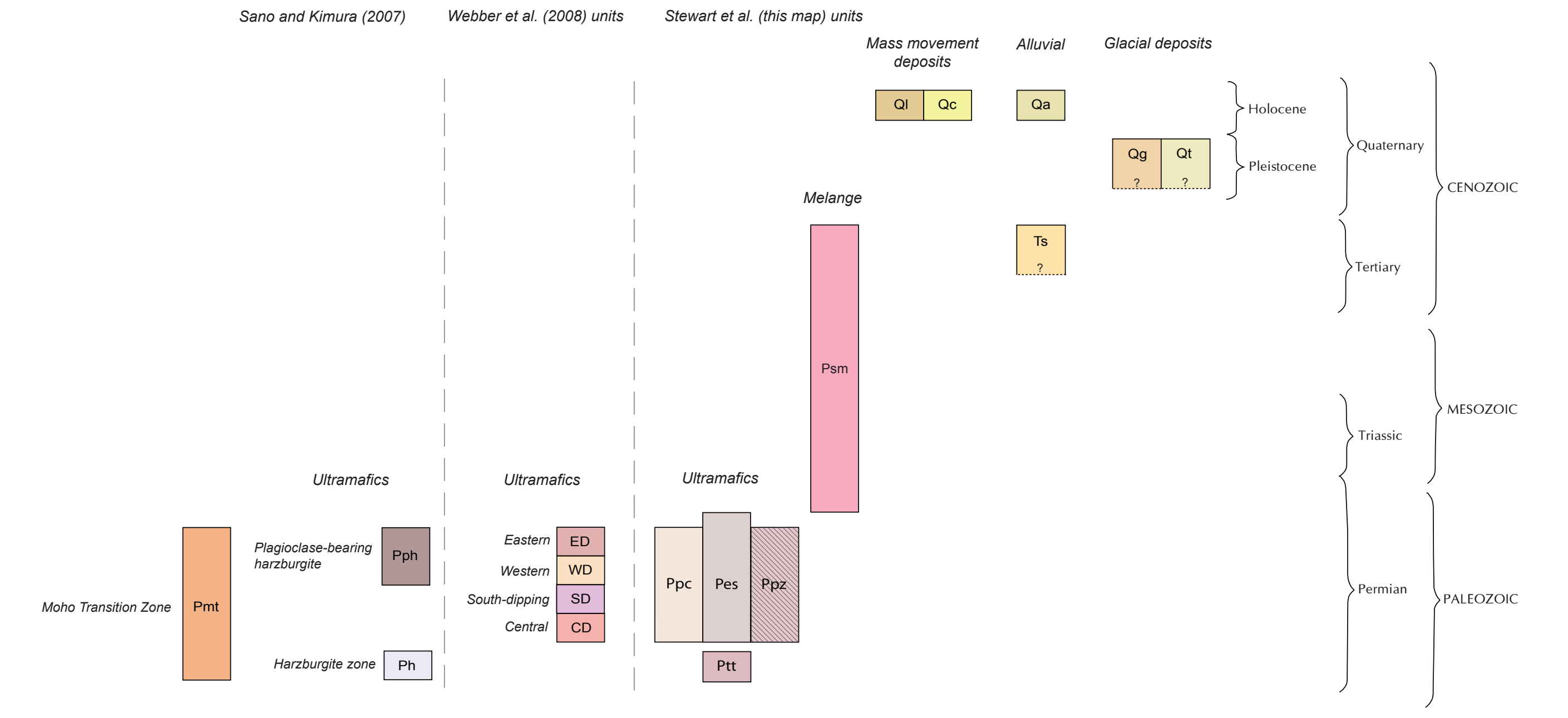
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

Contour interval 20 meters

New Zealand Transverse Mercator Projection
NZGD2000 Datum
Source: NZtopo50 vector data from LINZ

CORRELATION OF MAP UNITS



SYMBOLS

- Domain contact, solid where known, dashed where inferred, dotted where covered
- Strike-slip fault, solid where known, dashed where inferred, dotted where covered
- Normal fault, ball and bar on downthrown side, solid where known, dashed where inferred, dotted where covered
- 78 Strike and dip of compositional banding
- Strike and dip of vertical compositional banding
- 78 Strike and dip of pyroxene or spinel mineral cleavage (shape preferred orientation)
- 78 Strike and dip of plagioclase mineral cleavage (shape preferred orientation)
- 78 Strike and dip of both compositional banding and mineral cleavage
- 30 Trend and plunge of spinel or pyroxene mineral lineation
- 30 Trend and plunge of plagioclase mineral lineation
- Mafic dike
- Plagiogranite dike
- 49ES08 Sample location
- A A′ Surface trace of cross-section

INTRODUCTION

1:20,000 scale geologic mapping was undertaken during the Austral summers of 2010-2011, 2011-2012, and 2013-2014 in the Red Hills ultramafic massif in an effort to characterize the spatial scale of heterogeneous mantle fabrics. Previous work in the vicinity of Porters Knob showed that the deformational fabrics present in the rocks were created at upper mantle temperatures and pressures (Webber et al., 2008; Webber et al., 2010). This map is a continuation of that project.

DESCRIPTION OF MAP UNITS

ALLUVIAL DEPOSITS

Qa

Alluvium (Quaternary) - Rounded to sub-angular ultramafic, mafic, and sedimentary boulders and cobbles mixed with sand and mud. Poorly sorted.

Ts

Sediments (Tertiary) - Rounded to sub-rounded locally-derived ultramafic boulders and cobbles mixed with sand and mud. Typically very poorly sorted but well cemented, forming spectacular, isolated ridgetop exposures above the Motueka River, Waimea River, and Porters Creek. Unconformably over the ultramafic rocks.

MASS MOVEMENT DEPOSITS

Ql

Landslide deposits (Quaternary) - Blocks of boulders, often within a serpentine-rich matrix. Common along the steep slopes of the Right Branch of the Motueka River.

Qc

Colluvium (Quaternary) - Angular ultramafic boulders and cobbles mixed with sand and mud. Poorly sorted. Locally derived.

GLACIAL DEPOSITS

Qg

Glacial deposits (Quaternary) - Poorly sorted ultramafic boulders and cobbles of glacial origin. Includes both glacial bowls and moraines.

Qt

Talus, undivided (Quaternary) - Highly angular ultramafic boulders and cobbles, making up parts of Porters Ridge and Red Hills Ridge. The origin of the talus is uncertain, but a colluvial origin is unlikely considering the low-angle slopes it is commonly found along. Pleistocene glaciers are tentatively inferred to have ground down rock outcroppings and locally transported the talus.

MELANGE

PTp

Patuki Melange (Permian-Tertiary?) - Serpentine melange forming the western, northern, and much of the eastern boundary of the Red Hills massif. Blocks of serpentinized ultramafics within a serpentine matrix are common near the boundary with the massif. Blocks of sedimentary and mafic rocks become more common away from the boundary with the ultramafics. The scale of the transition from unserpentinized peridotite to melange varies depending on the location in the massif. In the northwest corner of the massif, where the Patuki melange is thickest, the ultramafics are strongly serpentinized up to 1.5 kilometers from the mapped boundary, while in the north, east, and southwest portions of the massif, the ultramafics rapidly grade from unserpentinized peridotite into melange over only several hundred meters. Rodingite is common within the melange in the western massif, but was not observed in melange along the northern and eastern boundary of the massif. Serpentine foliations strike approximately N-S and dip vertically on the western and eastern boundaries of the massif, and strike NNW and dip steeply to the SSW on the northern boundary of the massif.

ULTRAMAFIC MAP UNITS

Dun Mountain Ophiolite Belt

Pes

Ellis Stream complex (Permian) - Largely harzburgite (45%), and dunite (40%) with minor lherzolite (10%) and pyroxenite (5%). Significant local variability in lithology occurs, though in general relatively consistent lithologic packages exist which are between 10s and 100s of meters wide. The Ellis Stream complex becomes increasingly serpentinized to the west, and also contains more abundant rodingite dikes.

Compositional banding and mineral cleavages are oriented roughly N-S, dipping steeply west. Lineations plunge to the northwest with significant scatter. Pyroxenite bands in the eastern portion of the unit are variably folded, with fold types ranging from open to tight. Towards the western portion of the massif the pyroxenite dikes are generally more strongly deformed, often into isoclinal folds. The amount of deformation is locally very heterogeneous. A plagiogranite dike along Porters Ridge cross-cuts the steeply west-dipping compositional banding, and was dated to 274.55±0.43 Ma (Stewart et al., in review). This indicates the fabric was created prior to ca. 274.5 Ma.

Ppz

Plagioclase zone (Permian) - The plagioclase zone contains abundant plagioclase-lherzolite, plagioclase-harzburgite, and lherzolite, and is found along the western margin of the two tarns harzburgite. Pyroxenite and websterite bands occur throughout the zone, and dunite bands are uncommon. Plagioclase occurs as thin (mm to cm long) stringers, and its abundance waxes and wanes within tabular bands. Pyroxenite bands represent less than 10% of total exposure, and dunite less than 5%. The distribution of plagioclase lherzolite and plagioclase harzburgite at the sub-kilometer to kilometer scale is highly heterogeneous. Much of the area mapped as plagioclase zone contains large amounts of massive harzburgite typical of the two tarns harzburgite.

The plagioclase zone is characterized by strong, pervasive plagioclase foliations, and sometimes alignment of pyroxene and olivine. Plagioclase foliations locally overprint banded lherzolites and dunites near the contact between the plagioclase zone and the Plateau complex. Near the contact with the Plateau complex, plagioclase foliations have a mean orientation of 043/32SE, while in the north-central massif, plagioclase foliations typically dip to the southwest or northwest.

Ppc

Plateau complex (Permian) - The Plateau complex is composed dominantly of harzburgite with interlayered dunite bands. Banded lherzolite and dunite is less common. Large pods and sills of dunite and olivine-rich lherzolite occur throughout the unit, varying from meters to hundreds of meters wide. Plagioclase lherzolites are found sporadically across the unit.

Harzburgite and dunite compositional banding is usually strong. Pyroxene and spinel cleavages often parallel the compositional banding. Olivine-rich pods (either dunite or olivine-rich lherzolite) generally have very weak planar and linear fabrics. Throughout much of the northern and southwestern portions of the unit, an early E-W striking, north-dipping fabric is partially overprinted by a NE-SW striking, SE-dipping fabric. Planar and linear fabrics associated with the SE-dipping event vary in orientation and strength on the scale of several meters to several hundred meters.

Ptt

Two tarns harzburgite (Permian) - Dominantly harzburgite. Uncommon dunite bands and rare dunite pods occur throughout the unit. Pyroxenite bands are common throughout, but overall are less abundant than in neighboring lithologic units to the west. Plagiogranite and basaltic dikes are rare.

This unit generally has a massive fabric. Foliations, where present, are typically poorly developed and have highly variable orientations. However, the rocks contain a pervasive, consistent lineation that averages 20 at 063. Pyroxenite bands are randomly oriented.

STRUCTURES

DUCTILE SHEAR ZONES

ELLIS STREAM SHEAR ZONE

The Ellis Stream shear zone (ESSZ) is a shear zone within the Ellis Stream complex, and is oriented approximately N20W/90. The shear zone is exposed on the hanging wall side of the Boulder Creek fault, but not on the footwall. The shear zone can be divided into a core and periphery, with the core occupying much of the southwestern portion of the Ellis Stream complex. The core is characterized by well-aligned foliations, whereas the periphery contains less well aligned foliations, often dipping less steeply to the west. Only half of the shear zone is exposed, as the western side of the shear zone is cut by melange.

Shear sense indicators in outcrop, as well as an overall steepening of foliations from east to west, indicate east-side up motion. Lineations pitch variably to the northwest, and are typically not parallel to the shear direction.

MELANGE

PATUKI MELANGE

Johnston (1982; 1983; 1990) previously mapped the melange bounding the Red Hills complex. Based on map patterns and lithologic differences between different parts of the melange, we tentatively divide the creation of the melange into three separate stages which we describe in more detail below: first, melange development along the northwestern edge of the massif; second, melange development associated with the Red Hills fault and along the eastern boundary of the massif; third, melange development associated with the Maitland Creek fault.

We interpret the earliest episode of melange development to have occurred along the northwestern edge of the massif, between Porters Creek hut and Hunters hut. There, the serpentine melange is significantly thicker, and transitions much more gradually into unserpentinized peridotite over a much longer distance. The melange also contains abundant rodingite dikes. This structure separates ultramafic rocks from mafic volcanic rocks of the Livingston Volcanics Group, both of which are part of the Dun Mountain ophiolite belt. The melange likely once accommodated normal motion, placing mafic volcanics over ultramafics, but has since been rotated, along with the overlying Maitai Group, to a subvertical orientation. Based on geobarometry estimates for the ultramafic massif of roughly 5 kbar, several kilometers of mafic crustal rocks as well as several kilometers of ultramafics rocks are likely missing as a result of movement along the melange.

Melange along the Red Hills fault and along the eastern boundary of the massif developed from thrusting the ultramafic rocks of the Red Hills over the sedimentary rocks of the Caples terrane. We interpret this thrust-related stage of melange development to have occurred after development of extension-related melange in the northwestern edge of the massif. Simultaneous melange development from thrusting and extension would require the ultramafic body to have risen to the surface within a channel, but the size of the ultramafic massif makes this possibility unlikely.

Finally, melange associated with the Maitland Creek fault along the southwestern edge of the massif was likely the last melange to develop. The Maitland Creek fault truncates the trend of the Dun Mountain ophiolite belt. More details on the Maitland Creek fault are given below.

FAULTS

MAITLAND CREEK FAULT

The Maitland Creek fault was mapped by Walcott (1969) and Johnston (1990), though they did not name the structure. The fault strikes north-south and dips sub-vertically. The fault places ultramafic rocks adjacent to mafic volcanic and carbonate crustal rocks. The fault is characterized by an approximately 500 meter thick melange consisting of a serpentine matrix surrounding serpentinized peridotite, rodingite, mafic volcanic, and very rare limestone blocks. An additional approximately 500 meters of ultramafic rocks adjacent to the fault are moderately serpentinized. Crustal rocks are altered only immediately adjacent to the fault.

The fault is interpreted to be a reverse fault that places ultramafic rocks over crustal rocks. The exposed sub-vertical dip at the surface requires the fault to turn listric at depth. The fault is interpreted to be a significant structure, changing the orientation of the western boundary of the ultramafic belt from northeast (everywhere north of Porters Creek) to north-northwest, and resulting in shortened ultramafic and mafic sections. The age of the fault and associated melange is uncertain, but is tentatively interpreted to be younger than other faults and melange in the Red Hills, as it truncates the trend of the Mesozoic Nelson regional syncline. It may be a Cenozoic structure associated with movement on the Alpine fault.

LATE-STAGE STRIKE SLIP FAULTS

A series of late-stage, west-northwest striking, sub-vertical faults occur throughout the massif. These faults are characterized by localized zones (ca. 30 meters) of intense serpentinization, brecciation and often are intruded by basaltic dikes.

Most faults have shallowly plunging lineations, left lateral shear sense indicators, and left-lateral offset of map units, indicating they are typically left-lateral strike-slip faults. They have relatively minor offsets, typically one kilometer or less. The age of the faults is unknown, but must post-date the Porter fault, which they displace.

BOULDER CREEK FAULT

The Boulder Creek fault strikes north-northeast and dips steeply east, but curves eastward to the south. The fault is located within the Ellis Stream complex, and separates hanging wall rocks deformed by the Ellis Stream shear zone from footwall rocks that do not appear to be affected by the shear zone. This interpretation is difficult to verify along the western edge of the footwall block due to strong serpentinization. The fault is characterized by breccias and an approximately 50 meter wide zone of intense serpentinization.

Fault kinematics were not directly observed, but are inferred based off of map patterns. If the footwall rocks are not part of the Ellis Stream shear zone, then several kilometers of apparent left-lateral slip is required to place shear zone rocks adjacent to rocks not deformed by the shear zone. However, to the south, the vertically-dipping bounding melange (PTp) has minor apparent left-lateral offset across the fault. To account for this difference, we interpret the Boulder Creek fault to be an oblique left-lateral reverse fault where it strikes northeast, but as the strike of the fault curls northward it transitions into a left-lateral strike slip fault. The age of the fault is unknown, but is presumably post-Permian based on minor offset of the bounding melange.

RED HILLS FAULT

The Red Hills fault and associate melange have been mapped by Walcott (1969) as well as Johnston (1982). The Red Hills fault strikes west-northwest and dips steeply south. The fault proper is mapped at the contact between ultramafic rocks and crustal sedimentary rocks of the Caples Group. The Patuki melange map unit includes serpentinized ultramafic rocks as well as fault zone sedimentary rocks, and is widest along the northwestern edge of the massif, and tapers to the east. The contact between the ultramafic and crustal rocks is characterized by abundant breccias, and zones of strongly deformed lozenges of serpentinized ultramafics intercalated with fine-grained sedimentary rocks. The ultramafics are relatively unserpentinized to within approximately 300 meters of the contact.

We interpret the Patuki melange along the northern edge of the massif to result from movement of the Red Hills fault. Kinematics along the Red Hills fault were not consistent, perhaps the result of internally rotating blocks within the melange. However, some component of reverse motion is likely in order to place ultramafic rocks over sedimentary rocks. The age of the fault must post-date the Permian to Triassic rocks of the Caples Group cut by the fault.

PORTER FAULT

The Porter fault was first recognized by Johnston (1990). It is oriented approximately 200/70NW. The Porter fault separates the Ellis Stream complex from the two tarns harzburgite, plagioclase zone, and Plateau complex. The fault is characterized by a roughly 100 meter-wide zone of serpentinization, and where the fault crosses the Right Branch of the Motueka River, there is a roughly two-meter wide serpentine fault core. Plagiogranite, rodingite, and basaltic dikes are commonly intruded into the fault. The fault zone also includes zones of intense brecciation.

Shear sense indicators within serpentinized peridotites, deformed basaltic dikes and deformed plagiogranites suggest left-lateral motion. Lineations typically pitch shallowly to the south. Thus we interpret movement on the Porter fault to be dominated by left-lateral strike-slip motion, with a minor component of normal motion. The age of the fault is not directly known, but the fault is truncated by the Mesozoic Red Hills fault. We tentatively assign a Permian age to the structure.

ACKNOWLEDGEMENTS

Most contacts between melange units and surrounding sedimentary rocks come from Johnston (1982) and Johnston (1990). Thanks to Esther Stewart, Dana Peterson, Charlotte Buxton-Blue, Marco Billia, Zoe Reid-Lindroos, and Ewen Rodway for field assistance, and Dushan Jugum for helpful conversations.