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Society Field Trips in Pacific Northwest Geology

Geology of the Skagit Crystalline Core and the Northwest Cascades System, Marblemount Area

Fall, 1989

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Northwest Geological Society Field Trip, Fall 1989

Geology of the Skagit Crystalline Core and the Northwest Cascades System, Marblemount Area

E.H. Brown, Trip Leader

Introduction

Misch (1966) divided the rocks of the North Cascades into two groups: 1) the Skagit Crystalline Core (CC), dominated by plutons and high-grade schists and gneisses and 2) the Northwest Cascades System (NWCS), made up of thrust sheets of low-grade, high-pressure metamorphic rocks (Fig. 1). In the vicinity of Marblemount, the central area of our trip, these two contrasting rock complexes are separated by the Straight-Creek fault, a Tertiary (Eocene?), dextral strike-slip fault, thus primary relations can not be observed here between the CC and NWCS.

The metamorphic rocks of the CC are derived from sediments and volcanic rocks of recognizably different tectonic provinces, all broadly oceanic. On our trip we will observe an apparently coherent stratigraphic sequence representing a Triassic oceanic arc system of meta igneous and sedimentary rocks. This is part of the Cascade River Schist of Misch (1966). We will also observe a chaotic assemblage (melange) of oceanic floor lithologies dominated by metabasalt, but also including meta-shale, -gabbro, -basalt, and -peridotite. This rock is also part of Misch's (ibid) Cascade River Schist. The mutual relationship of these two units is currently debated. Tabor et al. (1989) suggest that the arc assemblage overlies the ocean floor assemblage in a more or less conformable fashion, and thus they interpret the two assemblages to be part of a single terrane; this is termed the Chelan Mountains terrane, and the two parts are termed the Cascade River unit and the Napeequa unit, respectively. An alternative view is suggested by our mapping: the oceanic melange overlies the arc sequence. Presumably this contact would have to be a fault, and thus perhaps two terranes should be recognized.

The igneous and sedimentary rocks of the Cascade River and Napeequa units, or terranes, are variably metamorphosed and deformed, are intruded by a number of plutons, and are transitional into the very high-grade Skagit migmatites. The nature and cause of this orogenic activity is also much debated. One interpretation, the most popular, is that the CC is a contractional orogen which underwent crustal thickening and attendant metamorphism, deformation and plutonism in a collisional zone

between North America and Wrangellia. (Misch, 1966; Monger, et al 1982; Brandon and Cowan, 1985, FlueGrodner, 1989; Whitney and McGroder, 1989). An alternative viewpoint is that the CC orogen represents an Andean-type magmatic arc intruded into already accreted terranes (Dickinson, 1976; Nelson 1979), and that deformation and metamorphism are primarily related to pluton emplacement, with a significant deformational effect caused by a syn-orogenic strike-slip fault system developed along the axis of the arc (Brown and Talbot in press).

On the first day of the field trip we will study features in the CC (Fig. 2) that document 1) the nature of protolith materials for the metamorphic rocks 2) the degree of metamorphism, 3) the kinematics and amount of deformation 4) the timing of metamorphism and deformation and 5) the nature of plutonism and its relation to metamorphism. Our discussion of these features will include consideration of the larger-scale tectonic questions.

On the second day of the trip we will study primarily the Shuksan 'metamorphic Suite' (of Misch, 1966) which is a component of the NWCS. We will not be able to visit the thrust zones of the NWCS as these are not exposed in our field trip area. Our attention during this day will be on features internal to the Shuksan Suite, including oceanic floor protoliths, and subduction zone metamorphic and structural features.

Day One Road Log

Mileage Stop (from east end of USFS 15)

0 1 9:15 a.m. Meet at end of Cascade River Rd. (USFS 15) in parking lot at trailhead for Cascade Pass.

Large outcrop in parking lot is mylonitic Eldorado pluton ("Eldorado Orthogneis" of Misch, 1966). Steep NW striking foliation and strong strike-parallel lineation. This fabric is pervasive along the SW contact of the Eldorado pluton with the Cascade River Schist and marks a strike-slip shear zone. The

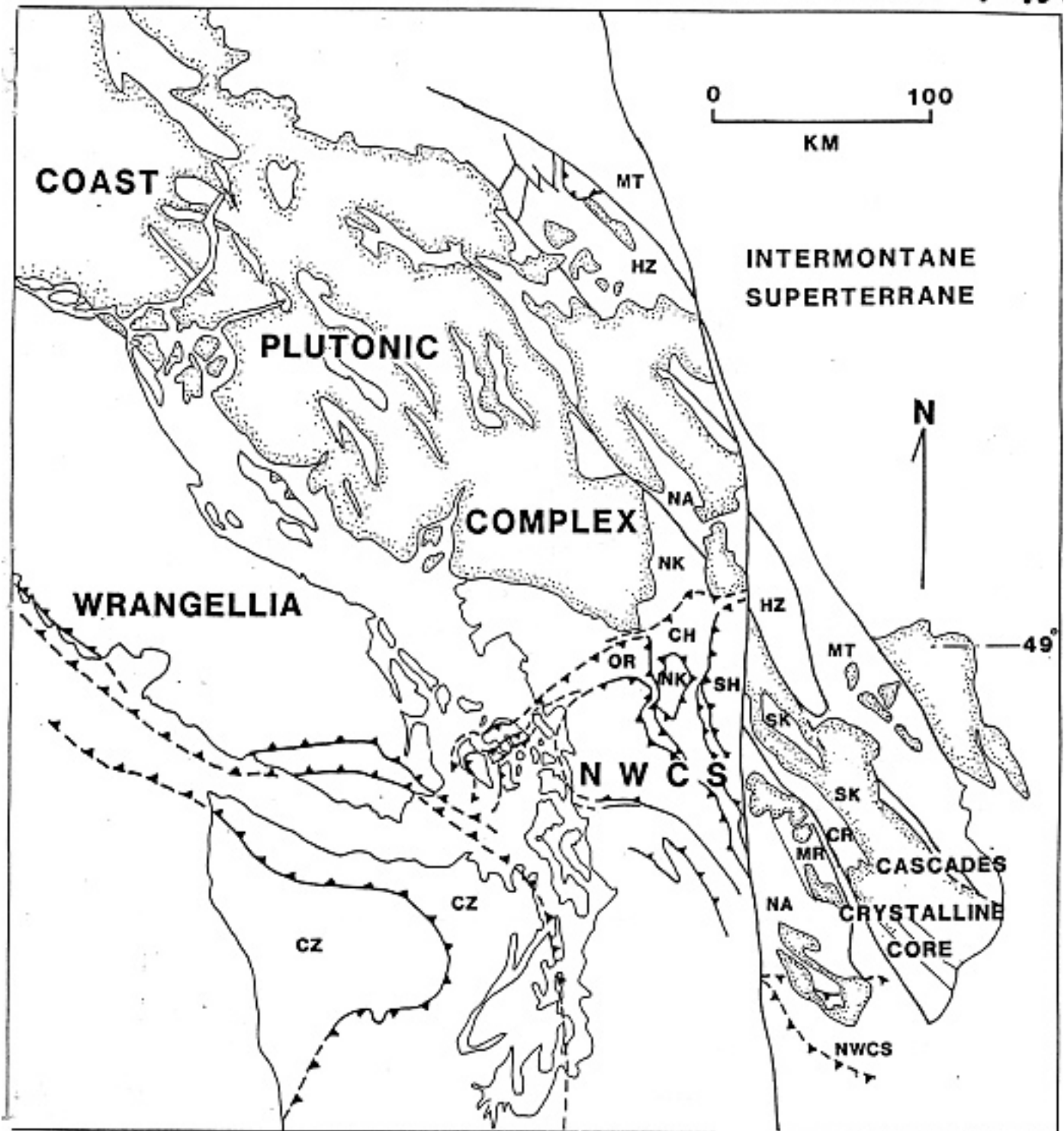


Figure 1. Tectonic elements of the Pacific Northwest. Terrane abbreviations are CH = Chilliwack, CR= Cascade River, HZ= Hozameen, MR = Mad River, MT= Methow, NA = Nason, NK = Nooksack, OR = Orcas, SH = Shuksan, CZ = Cenozoic, NWCS = Northwest Cascades System

age of the fabric is bracketed by the 92 Ma age of the Eldorado pluton and the 73 Ma age of the Hidden Lake Peaks pluton which overprints it.

View from here of Eldorado Peak.

0.2 **2** At close point of road to the Mo. Fk. Cascade River. Descend steep bank carefully. Outcrops on both sides of river are mylonitic Eldorado pluton. On the So. bank, S-C fabrics indicate dextral shear sense. Mt. Johannesburg is composed of the conglomerate facies of the Cascade River Schist unit. Boulders of this are observable in the river. Metamorphic grade here is lower amphibolite facies (oligoclase + hornblende + epidote; chloritoid + garnet). On the lower slopes of Mt. Johannesburg near here, outcrops of the conglomerate show a flattening fabric with post-tectonic garnets; overprinting is a strike-slip shear fabric associated with abundant chloritic alteration. The early fabric and metamorphism may be related to intrusion of the Eldorado pluton.

10.8 **3** The road crosses Hard Ck. Outcrops west of Hard Ck. are quartzose biotite schist. This is impure metachert of the Napeequa unit (terrane?). Follow small trail on west side of Hard Ck. to quarry and adit in a small schistose talc body. This material is interpreted to represent subocean mantle imbricated with the chert sea-floor sediments during terrane accretion. Also observe boulders of non-foliated, post-tectonic, 73 Ma Hidden Lake Peaks pluton in the Creek. Turn off on USFS 1550 and drive 7.8 miles to next stop.

from intersection USFS 15/1550

7.8 **4** Observe roadcut and knob above road. Marblemount Metaquartz Diorite (MMQD) of Misch (1966). Triassic zircons (221 Ma, Mattinson, 1972). Strong fabric, steep NU trending foliation, strike-parallel lineation, dextral S-C. View from here (in good weather) across Cascade River and Le Conte (Entiat) fault, from left to right, Marble Ck. pluton, Haystack pluton, Eldorado pluton, Hidden Lake Peaks pluton, all intruded into high-grade Cascade River Schist. Skagit gneiss in background.

The MMQD is interpreted to be a subarc plutonic body (Dragovich et. al. 1939) overlain more or less conformably by the metavolcanic and metasedimentary rocks of the Cascade River Schist. Directly in contact with the MMQD is meta-andesite and dacite yielding 220 Ma zircons (Stop 5), same age as MMQD zircons. Next in order is a coarse clastic unit with fragments of both the MMQD and andesite-dacite unit (Stop 6). Next and last in the succession is a pelitic unit with limey and volcanic interbeds (Stop 7). This stratigraphy is traceable on both sides of the Cascade River valley and appears to define a faulted syncline.

The Napeequa unit lies in the center of this structure and thus appears to overlie the Cascade River unit. The contact is presumably a thrust fault, as a conformable contact between melanged oceanic material (including mantle fragments), over an arc sequence seems impossible.

from USFS 15/50 intersection

4.8 **5** Greenschist derived from andesite of the Cascade River unit. Greenschist facies. A pressure of 3-4 kilobars is suggested by low *fla* content of actinolite. The metamorphic pressures on the other side of the Cascade River Valley, across the Le Conte fault is 9 kbars.

3.6 **6** Metaconglomerate with clasts of plutonic and volcanic rocks similar to lithologies in underlying units. Best observed by traverse 100-150 meters on small firebreak trail at top of clear-cut on west side of switchback. These are high-strain rocks with X/Z strain ratios of up to 30/1. The strain is constrictional. Dextral strike-slip is indicated by fabric orientation and S-C.

1.1 **7** Pelitic facies of the Cascade River Schist. Walk 150 meters up overgrown logging spur road. Meta-siltstone, -shale, -marl, -conglomerate. Locally bedded. Garnet, chloritoid, albite, muscovite, epidote, biotite.

from east end of USFS 15

13.4 Return to Cascade River Rd.

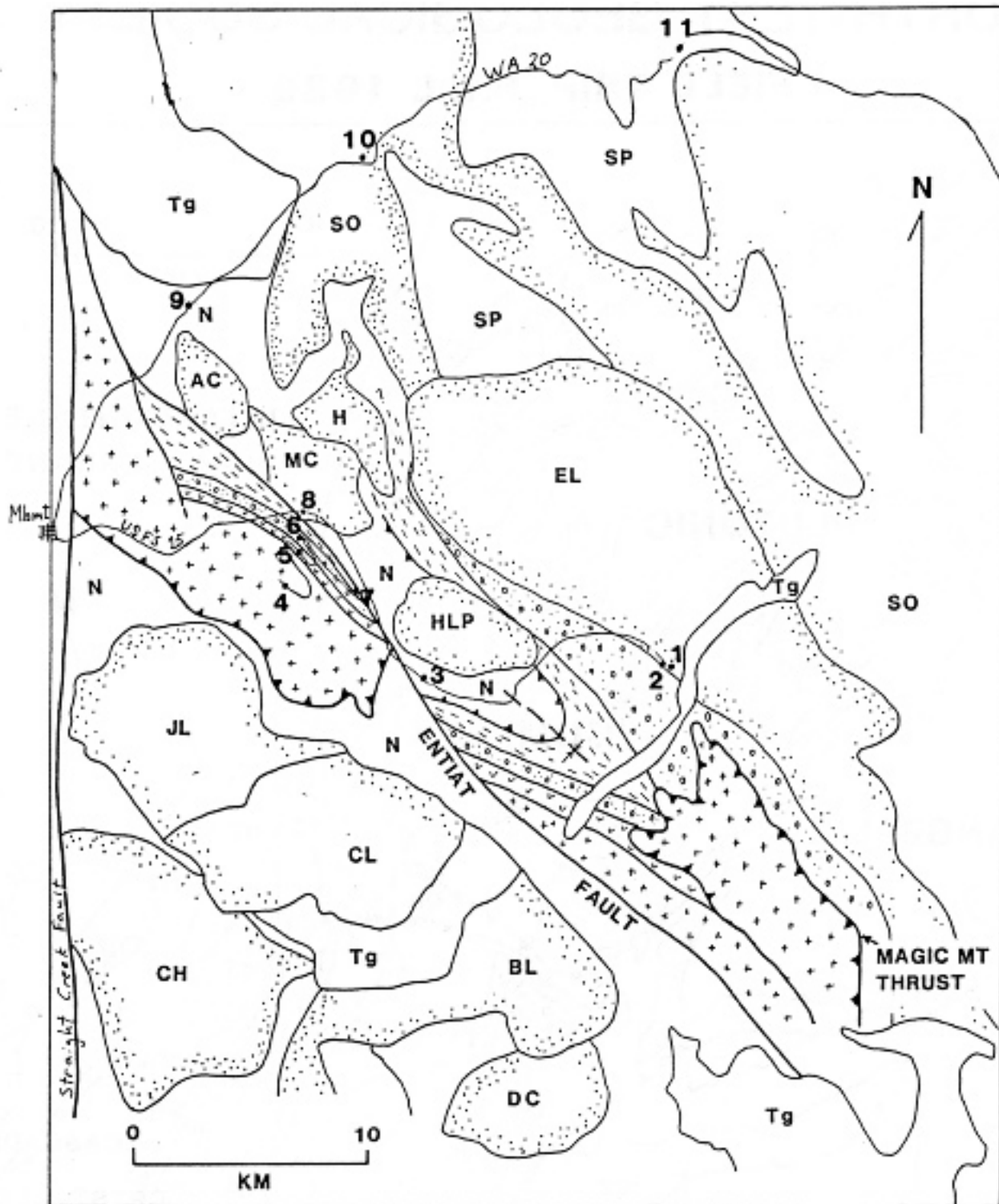
15.5 **8** Marble Creek. Good exposure of syntectonic Marble Creek and Haystack plutons in boulders in Creek bed. Best on downstream side of bridge, east side of Creek. The abundant felsic rock is Haystack. Look for large (1 cm long) igneous epidote, commonly with hbl core, indicating high pressure (> 6 Kb) crystallization. Hbl in Marble Ck pluton is Al-rich, indicating pressure of crystallization of 9 kbars (~30km depth).

24.3 Marblemount.





East on WA20 from Marblemount (WA20/USFS 15)

8.6 **9** Metachert of Napeequa unit.

24.0 **10** Newhalem. Observe Skagit gneiss in outcrops on north side of road. Hornblende-biotite tonalite orthogneiss. U-Pb zircon age is 65 Ma (Mattinson, 1972). Most of the Skagit gneiss is apparently orthogneiss. Zircon ages range to as young as 50 Ma. These rocks are syntectonic, with NW trending, low-plunge



Stratigraphy
of the
Cascade
River
Schist

-  Pelitic and Limey Facies
-  Feldspathic Clastic Facies
-  Andesitic-Dacitic Volcanic Facies
-  Quartz Diorite Facies
(Marblemount Metaquartzdiorite)

- AC = Alma Ck Pluton
- CH = Chaval Pluton
- CL = Cyclone Lake Pluton
- DC = Downey Ck Pluton
- EL = Eldorado Pluton
- H = Haystack Pluton
- HLP = Hidden Lk Pks Pluton
- MC = Marble Ck Pluton
- N = Napeequa Unit
- SP = Skagit Paragneiss
- SO = Skagit Orthogneiss
- Tg = Tertiary Granite

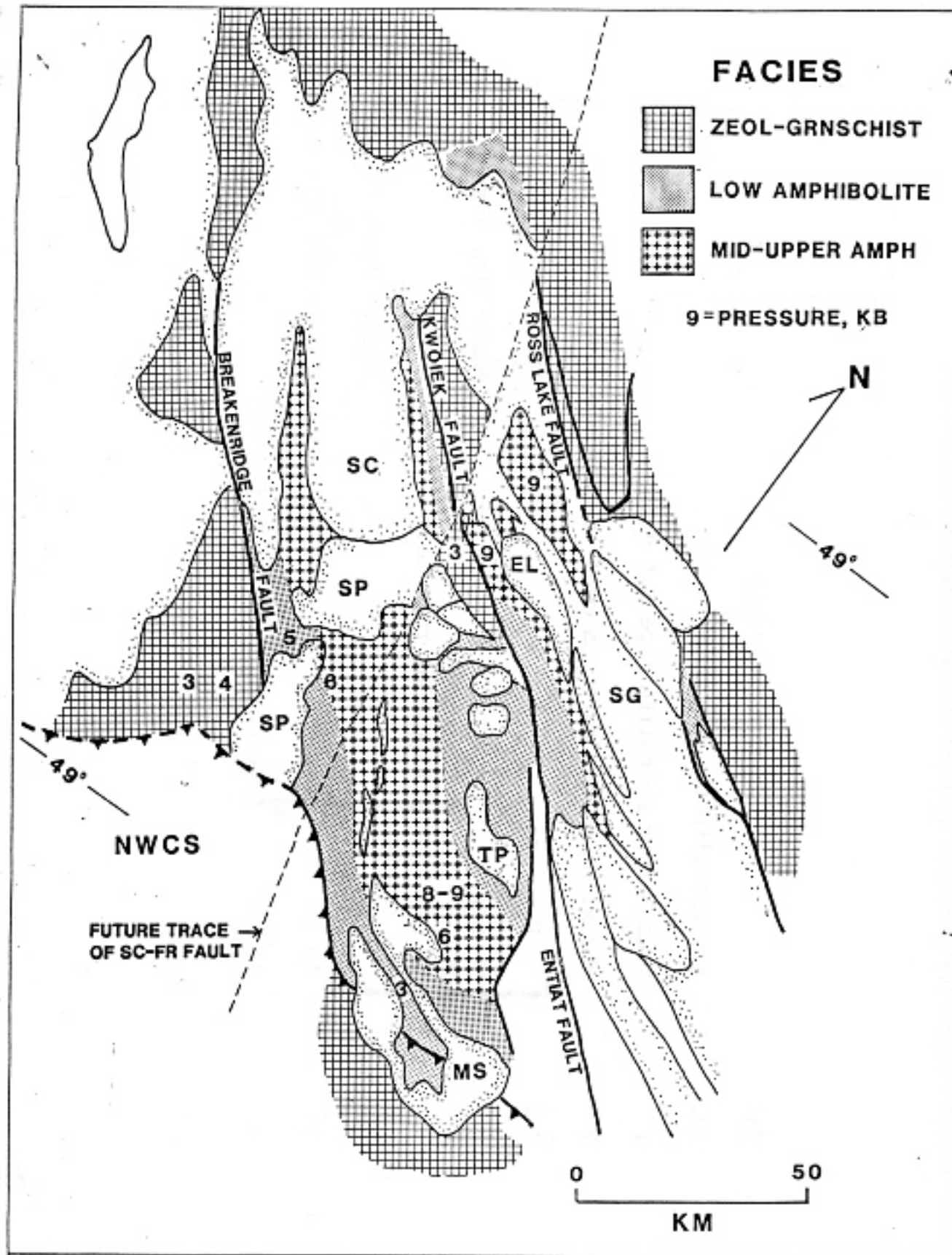


Figure 2 (Left) Geology of the Cascade River and Upper Skagit River areas. Field trips stops indicated with numbers. Based on Tabor et al (1989) with additions.

Figure 3 (Above) Preliminary map of metamorphic facies in the Cascades Crystalline Core and correlative Coast Range Plutonic Complex. Straight Creek - Fraser Fault is restored to match up metamorphic facies.

lineations. In contrast to the Cascade River area where deformation had ceased by 73 Ma, orogeny continued in the Skagit gneiss until after 50 Ma.

37.2 11 Horsetail Creek. Migmatitic Skagit paragneiss. This type of rock represents a metamorphic culmination in the Cascades. Pressures and temperatures estimated are 9kb and 720 respectively (Whitney and Evans, 1988). Whether the migmatites are anatectic or metasomatic is debated (see Babcock and Misch, 1979 for a recent discussion). Look for biotite gneiss, deformed pegmatites, green anthophyllite-biotite ultramafic rock, rare metachert, late cross-cutting orthogneiss dikes.

End of Day One.

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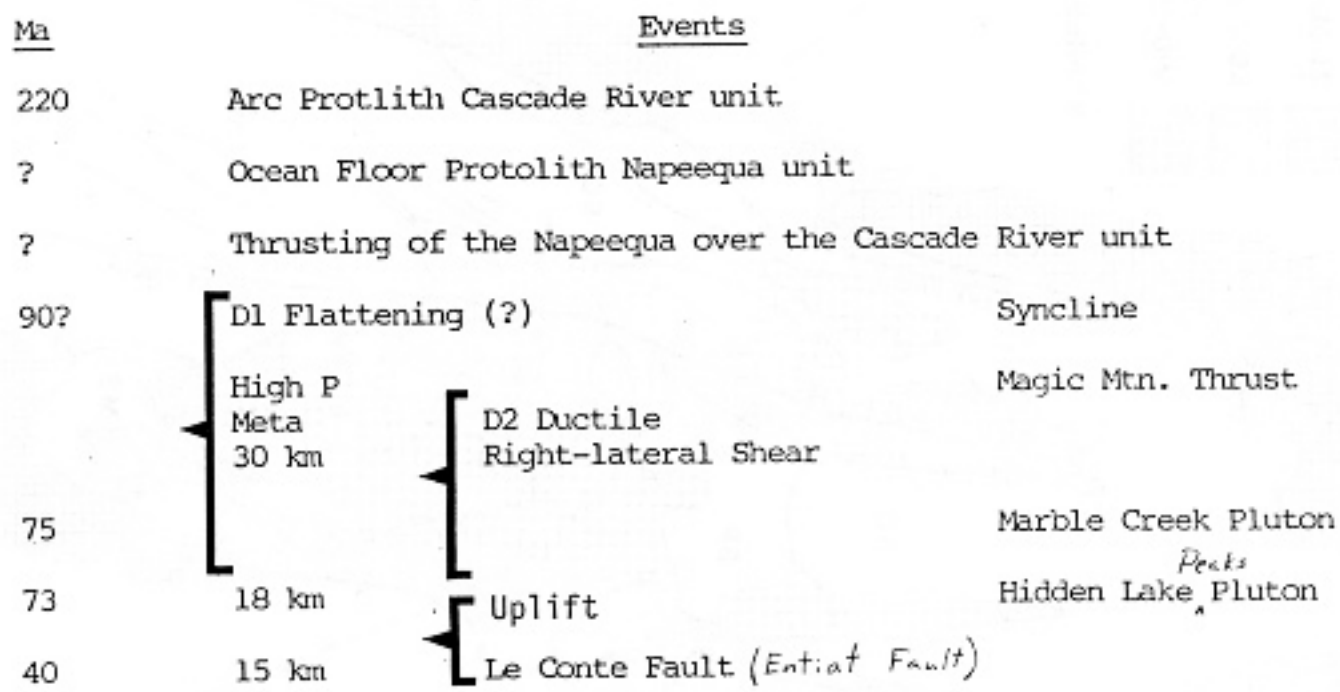


Figure 4 Tentative geologic history of the Cascade River Area

Day Two Field Guide

(Adapted from 1983 Penrose conf. field guide)

All stops are in the Shuksan Suite in the vicinity of Gee Point (Fig. 1 and 2) which lies south of the Skagit River. Stops A and B are roadside exposures showing typical lithologies, mineralogy and metamorphic structures within the regional blueschist terrane.

Stop C is an off-road locality where numerous excellent exposures of serpentinite and related garnet amphibolite and metasomatic rocks can be observed. A round-trip walk of approximately 1.5 miles and an elevation gain and loss of 800 feet are required. 1.0 mile of the walking distance is on a good trail, the remaining portion is through a logged area where there are some inconvenient downed logs, branches and loose rocks to negotiate. It is advisable to wear boots, and to bring sun protection and drinking water. 3 to 4 hours will be spent at this locality.

The geology at locality C is described in a recent paper by Brown and others (1982) which is included here as part of the trip guide. Geologic relations in the Gee Point area are complex, not completely known, and are the subject of ongoing research.

The Gee Point area is reached by travel up the Skagit Valley on Highway 20 to a point just west of Concrete where one turns south to cross the river and then proceeds east along the south side of the valley to the Finney Creek logging road. This is a one-lane, paved road, heavily used by logging trucks, the drivers of which are only expecting to meet traffic which has been announced over CB radio. So, lacking a CB radio, one must proceed with caution, especially at corners.

At 10.5 miles on this road, turn off to the right on road 1720. Proceed 1.0+ miles to service road 1721. Locality A is on the left .65 miles along this relatively rough road.

To reach locality B, return to 1720 and turn right, going up along 1720 4.4 miles from 1721 (passing a turnoff on 1722). The starting point for locality C is 6.2 miles from the 1721/1720 junction.

Locality A,

Preserved stratigraphy of metabasite (greenschist), Fe-Mn formation and pelitic schist is displayed (Fig. 3). The beds are deformed into F2 folds. Such folds are abundant in this area, where they range in size from microscopic crenulations to megascopic folds mappable by tracing metabasite/metasediment contacts (Morrison, 1977). The metabasite is greenschist containing-quartz + albite + epidote + chlorite + actinolite + sphene. The Fe-Mn metasediment contains magnetite + hematite + quartz + spessartine garnet + crossite + stilpnomelane + aegerine. In the pelitic schist are quartz + albite (porphyroblasts) + muscovite + epidote + chlorite + sphene + carbonaceous material + lawsonite.

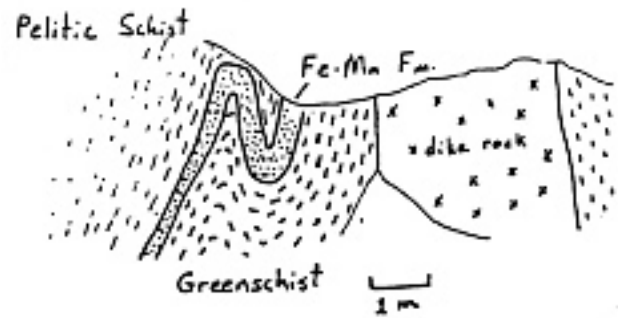


Figure 1 Sketch of outcrop at locality A

Locality B^

From this viewpoint, the serpentinite and amphibolite outcrops of locality C are observable across the valley in the clear-cut area. The structures and mineralogy observable at locality B appear to overprint rocks at locality C. Actinolite and crossite grains at B have hornblende or barroisite cores. Hornblende at C has actinolite or crossite rims and fracture fillings. S^ at B appears to overprint amphibolites at C. ?2 folds mapped in the regional schists at B are also mappable, with the same orientation, at C. From these observations, Wilson (1978) and I have concluded that the amphibolite complex was incorporated into the protolith materials of the regional Shuksan schists prior to or during the regional metamorphism.

At locality B, walk down the road to the end of the outcrop (.4 mile) observing interlayered Shuksan lithologies: greenschist, blueschist, quartz schist, muscovite schist, carbonaceous schist, iron formation. A temperature of 350°C was inferred for this outcrop from $^{40}\text{Ar}/^{39}\text{Ar}$ partitioning between quartz and magnetite (Brown and O'Neil, 1982).

Locality C

Walk undrivable spur road 017, branching to the right at a small saddle, approximately 10 minutes to the first outcrop (Fig. i4).

STOP 1 is foliated serpentinite on the left side of the road. Foliation is defined by magnetite clusters and platy texture of antigorite. The foliation is parallel to the regional Shuksan S]. Brucite, magnesite, chlorite, and rare diopside and andradite are accessory minerals.

Continue on road 50 meters around the corner to a small creek (may be dry), then walk up in the vicinity of the creek climbing about 200 vertical feet to a knob on the left.

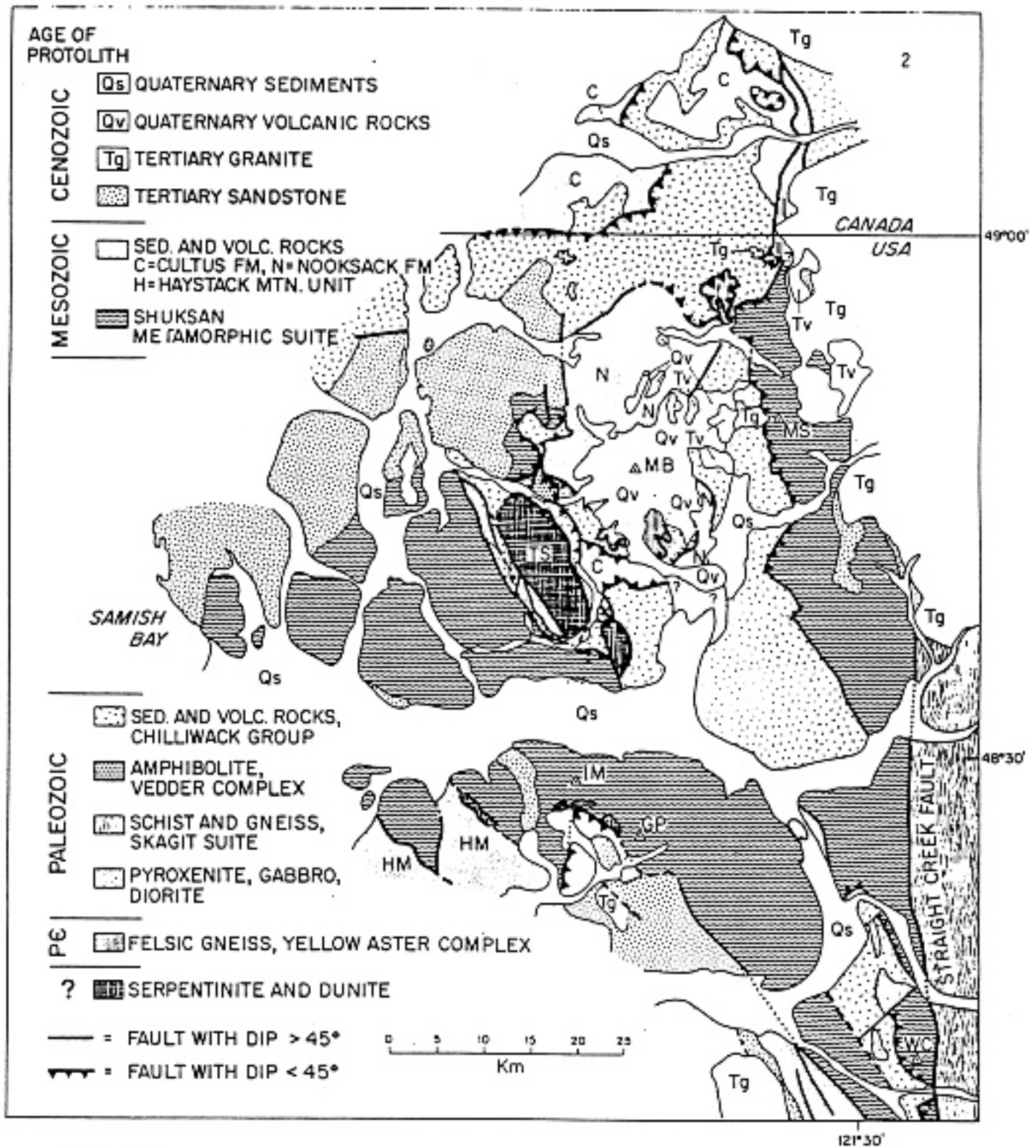


Figure 2 Regional geologic map of the Shuksan Metamorphic Suite, based on Brown and Others (1987)

IM = Iron Mountain, MB = Mount Baker, TS = Twin Sisters, MS = Mount Shuksan, GP = Gee Point, WC - White Chuck Mountain

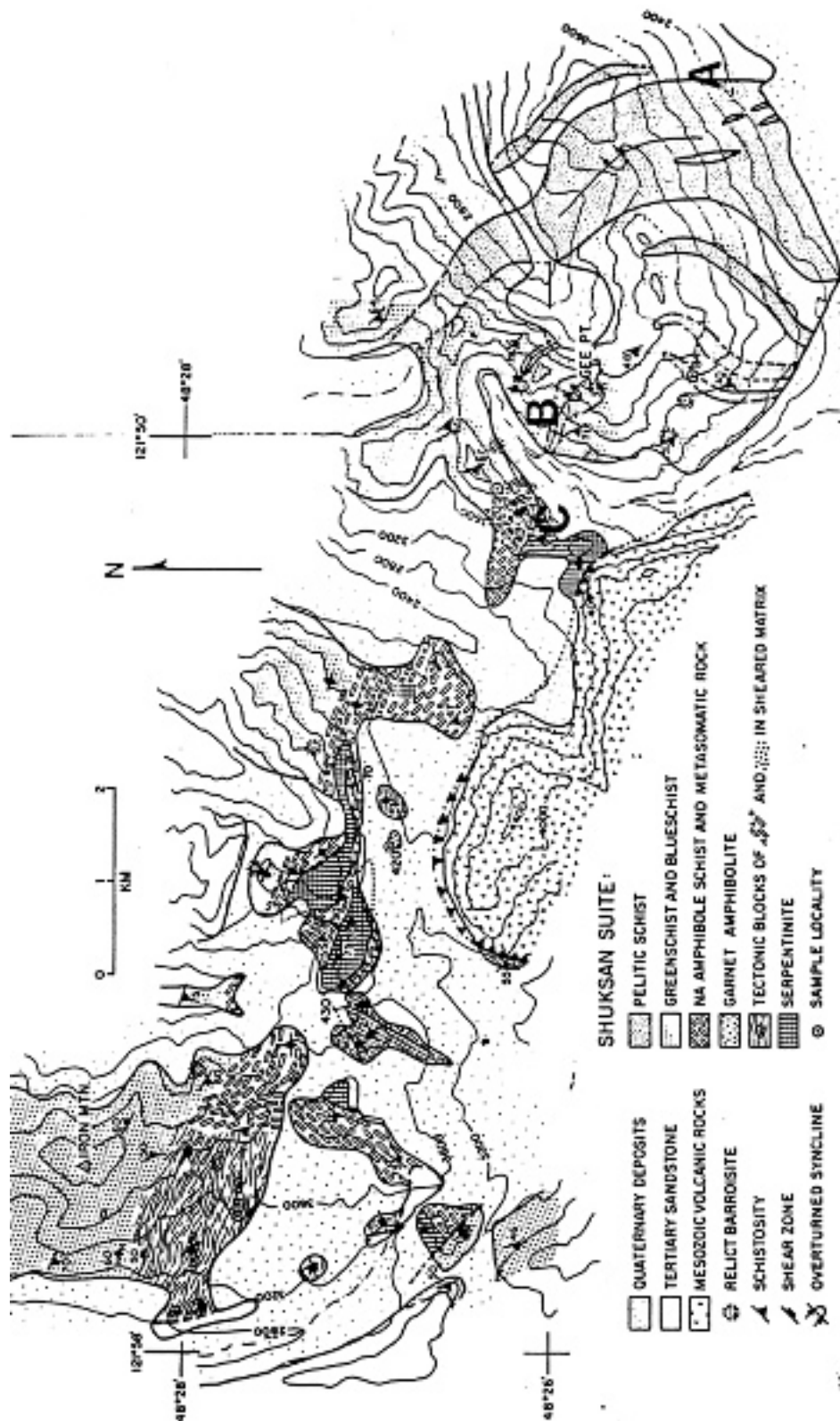


FIGURE 2. Geologic map of the Iron Mountain-Gee Point area. Geology in the vicinity of Gee Point by Morrison (1977), elsewhere by Brown. Contour interval = 400 feet. Field trip localities A, B, and C are shown. Modified from Brown and others (1982).

STOP 2 Garnet (40% grossularite) + salite rock occurring as an enclave within serpentinite. Garnet veins and irregular patches. This rock is perhaps a high-grade rodingite. Garnet-pyroxene temperatures are 700-800°C for similar rocks in the region based on the Ellis and Green (1979) geothermometer, but I think this calibration incorrectly treats the effect of grossularite in the garnet, and overestimates the temperature of this rock.

STOP 3 Fine-grained quartzose, carbonaceous, garnet hornblende schist. Well foliated.

STOP 4 Non-foliated albite + tremolite-actinolite rock. Mg chlorite, clinozoisite, sphene and jadeite-omphacite are accessory minerals. Some Na-pyroxene veins and albite veins. No quartz in this rock.

STOP 5 Foliated serpentinite with tremolite.

STOP 6 Coarse, well-foliated, folded muscovite schist with patches of talc-tremolite metasomatic rock.

STOP 7 Coarse tremolite metasomatic rock occurs as lenses in muscovite schist. Lenses are broken; they have been strongly deformed after their formation — a deformation probably related to that producing S¹ in regional Shuksan rocks. More and better exposures of this rock will be seen later (Stops 8 and 11). There are nasty logs to cross to get to Stop 7, so pass it by with no important loss of observation.

STOP 8 Talus with blocks representing lithologies from outcrops above. Observe: deformed coarse tremolite-talc rock, garnet amphibolite, garnetite, coarse muscovite schist, quartzite. The association of amphibolite, quartzite and muscovite schist possibly represents an oceanic crustal protolith. The talc-tremolite rock is blackwall material produced by metasomatism in a high temperature contact zone between ultramafic rock and amphibolite/mica schists. We interpret the garnetite to also be a high-grade blackwall metasomatic rock. This is a virtually identical association to that seen between basic gneiss and ultramafic rock on Catalina Island, California. The strong fabric in the high grade rocks indicates a dynamic type of metamorphism. We speculate that this metamorphism was caused by slices of hot ultramafic rock faulted into an oceanic crustal protolith.

STOP 9 Serpentinite with coarse radial chlorite and finer tremolite.

STOP 10 Amphibolite, quartzite, coarse muscovite schist. Strong deformational fabric. Isoclinal folds. Hornblende from this locality gave a K/Ar age of 148 ± 5 m.y.; muscovite on the nearby hill at locality 45 gave K/Ar age of 164 ± 6 m.y.; nearby regional schists give concordant K/Ar and K_b/Sr ages of 129 ± 5 m.y. (Armstrong dates).

STOP 11 In this area, garnet amphibolite containing brown hornblende occurs in a thin layer (1-10 meters wide) between serpentinite and Na-amphibole schist. The Na-amphibole schist is in most places barroisite-bearing, but glaucophane is the

primary amphibole in some rocks. Garnet is present in this Na-amphibole unit only near the brown hornblende band. Some rocks in the transition zone between the brown hornblende amphibolites and the Na-amphibole schists contain almandine garnet + glaucophane + albite, others contain glaucophane + omphacite + albite. Near Iron Mountain, the eclogitic assemblage garnet + omphacite + glaucophane + albite is observed. Rocks at this locality tend to be strongly retrograded, and distinction of primary and secondary assemblages is not always easy. Pumpellyite, actinolite, Fe chlorite, and crossite are abundant late stage minerals developed along a secondary foliation. More mineralogic and textural study is needed here. The question of a possible primary metamorphic gradient is not resolved inasmuch as clear primary isogradic reactions have not been defined. Note coarse-grained tremolite lenses deformed by late foliation.

STOP 12 Talus of regional blueschists and greenschists. Crossite and actinolite in these rocks have barroisite cores.

STOP 13 Coarse barroisite schist.

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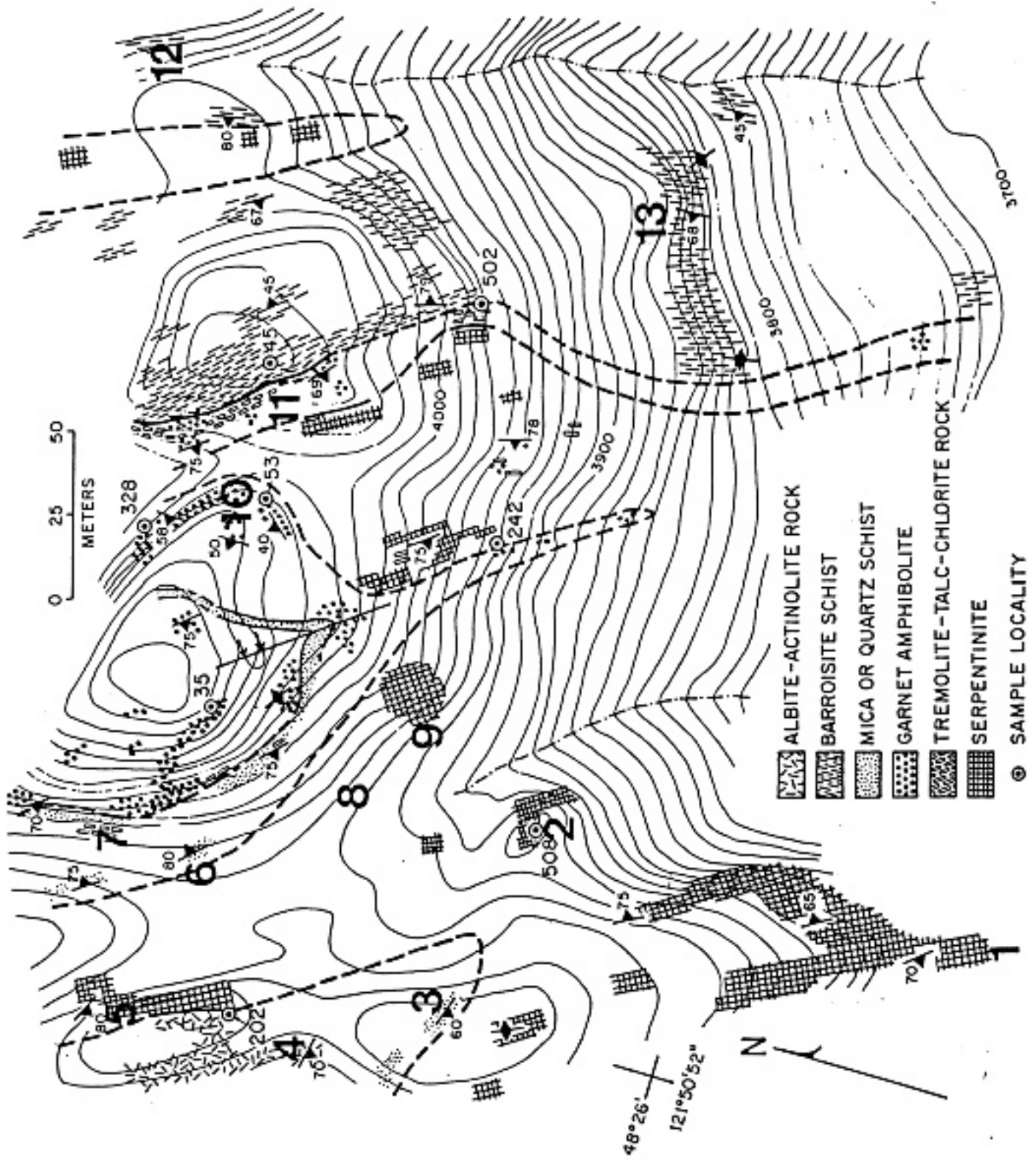


FIGURE 4. Geologic map and stops at locality C. Modified from Brown and others (1982).

