Northwest Geological Society

Society Field Trips in Pacific Northwest Geology

The Geology of Northeastern Washington

September 1993

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Guide to the Geology of Northeastern Washington

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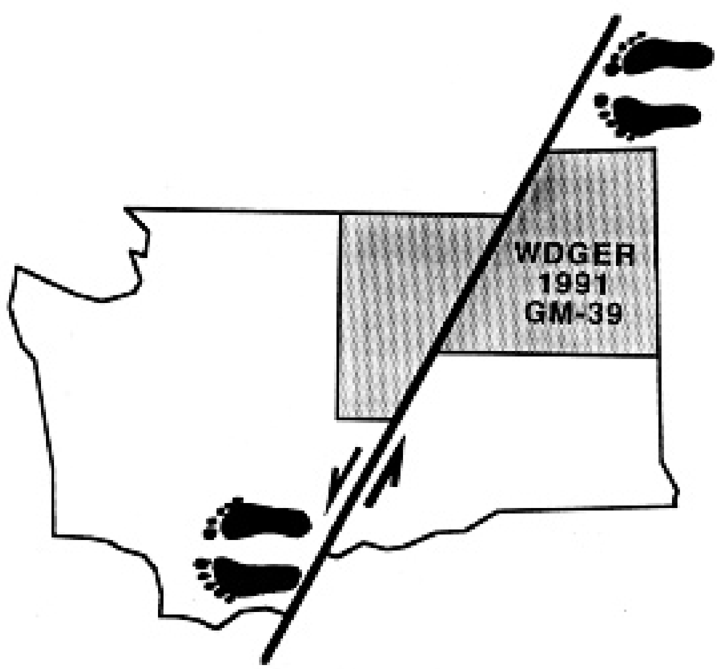


INTRODUCTION

Figure 1 shows the regional geological units of Washington: North American unconformity-bounded stratigraphic se¬quences, metamorphic core complexes, accreted terranes, and batholiths. The pur¬poses of this field trip are to (1) inspect the regional units of northeastern Washington (east of 120°W and north of 48°N, and (2) gain some insights on how they relate to each other.

This field guide is not an exhaustive guide to the geology of northeastern Washington. McKee's lucidly written Cascadia, published immediately before the dawn of plate tectonics (1972) is an interesting historical benchmark. Monger and others (1982) outlined the terrane concept for the Pacific Northwest. The Washington Division of Geology and Earth Resources has issued a number of publications (Schuster, 1987; Joseph, 1989; Stoffel and others, 1991; Lasmanis and Cheney, 1993) that include regional overviews of the northeastern part of Washington. The annual meeting of the Geological Society of America and other geological societies in Seattle in October 1994 will generate additional field guides and review articles. Other volumes that dealt at least partially with northeastern Washington are Riedel and Hooper (1989), Galster (1980), and Ross (1991). Derkey and others (1993) described the economic geology and current prospecting activities in more detail than this guide. The most important reference is the 1:250,000 map of northeastern Washington by Stoffel and others (1991).

ITINERARY

This is an ambitious four-day field trip. The first day is consumed by driving from Seattle to northeastern Washington. East of Wenatchee most of this drive is on the Columbia River Basalt Group.

The second day is a transect across units that are indigenous to pre-Mesozoic North America, the Ordovician to Carboniferous eastern assemblage, and portions of the Kettle metamorphic core complex. The transect begins at Deer Lake south of Chewelah and proceeds through Colville to Republic. The second night will be in Republic. There we will have a joint meeting with our sister society, the Northeastern Washington Geological Society (NEWGS). The meeting will feature snacks, a cash bar, and a short lecture on aspects of the geology of northeastern Washington.

During the third day we will examine Quesnellian rocks and the unconformably overlying Eocene Challis rocks in the Republic area. Geologists of Echo Bay Minerals Co. will lead a tour of the Key West gold deposit and nearby outcrops. The trip then heads westward to examine the Okanogan metamorphic core complex and more Quesnellian rocks. The third night is in Oroville.

The fourth day is spent examining tectonic relationships of pre-Tertiary rocks in the Okanogan Valley. Departure from the Omak area will be in the early afternoon. The trip then heads southward across the Columbia Plateau via Waterville to glimpse some of the Tertiary unconformity-bounded sequences, Pleistocene features, and the Chiwaukum graben at Wenatchee. The trip ends in East Wenatchee at dusk; Seattle is a three-hour drive to the west.

REGIONAL GEOLOGIC UNITS

INTRODUCTION

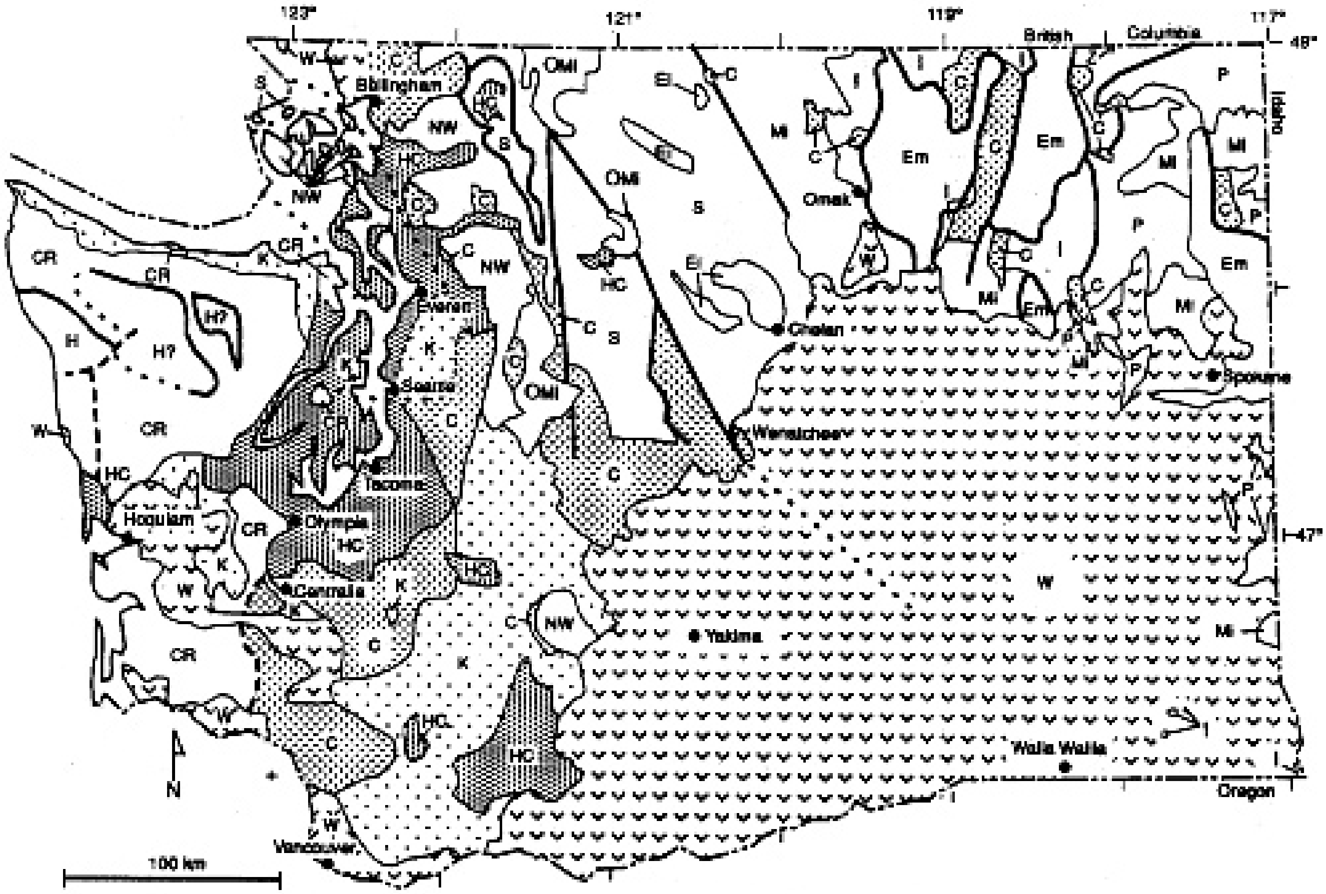
This section is an overview of the area crossed by the field trip. This guide accepts the importance of unconformity-bounded sequences in sedimentary and volcanic rocks. Sequence stratigraphy commonly has not been utilized in Washington and other parts of the Pacific Northwest. A sequence may be defined as a reasonably conformable succession of lithostratigraphic units (formations or litho-facies) bounded above and below by unconformities or their identifiable correlative conformities. Readers unfamiliar with sequence stratigraphy will find a brief explanation in Cheney in Lasmanis and Cheney (1993). Those unfamiliar with the nomenclature, definition, and ages of North American sequences can review Sloss (1988); unfortunately, Sloss did not discuss Washington. Sequences are the natural units to depict on maps ranging from 1:250,000 to 1:5,000,000. The boundaries of major sequences in the Pacific Northwest do not correspond to the paleontologically defined chronostratigraphic units (such as Precambrian, Cambrian, Miocene, etc.) that geologists have created (and still debate) as a basis for correlation on a worldwide basis.

PRE-MESOZOIC NORTH AMERICA

The rocks of pre-Mesozoic North America extend westward to at least the Columbia River (Figs. 1, 2, and 3). They consist of unconformity-bounded se¬quences younger than 1.5 Ga and an older crystalline basement. The crystalline base¬ment is exposed as some of the rocks in metamorphic core complexes (MCC). As structural entities, the MCC evolved in the Eocene; hence, they will be discussed later. The oldest known rocks in Washington are paragneisses about 1.7 Ga in the Priest River MCC east of Spokane and in the Kettle MCC near the International Border (Armstrong and others in Ross, 1991).

The Proterozoic and Paleozoic sequences were deposited off the trailing edge of the continent as miogeoclinal prisms. They are considerably thicker in Washington than in the cratonic interior. A plethora of lithostratigraphic names (Fig. 4) in Washington and adjacent British Columbia obscures the stratigraphic continuity of these rocks. Figure 5 organizes the lithostratigra

Figure 1. (facing page)
REGIONAL GEOLOGY OF WASHINGTON.
Modified from Cheney, Fig. 11, in Lasmanis and Cheney (1993). The horizontal wavy lines in this and other figures represent unconformities.



EXPLANATION

SYMBOLS	Age	Post-accretionary Units	Accreted Terranes (age of accretion)	North American Sequences
Faults (dotted where covered, dashed where inferred)	Oligocene to Pleistocene			HC - High Cascade
			H - Hoh	W - Walpapi
		OMi - batholiths		K - Kittitas
Contacts (dotted where covered, dashed where inferred)	Eocene	Em - metamorphic core complexes Ei - batholiths	CR - Coast Range	C - Challis
	Cretaceous		NW - Northwest Cascade S - Insular	Z - Zuni
	Jurassic	Mi - batholiths	I - Intermontane	
	Proterozoic and Paleozoic			P { Kaskaskia, Tippecanoe, Sauk, Proterozoic

phy into the sequence stratigraphy that is well known (Sloss, 1988) elsewhere in North America.

Different belts of Beltian rocks in Washington are not quite as correlative as Figure 4 implies. The rocks southeast of Chewelah are typical of the lower and middle Belt Supergroup of northern Idaho and adjacent Montana but different than the Deer Trail Group west of Chewelah (Miller and others, 1975). The Deer Trail Group also is known informally as the magnesite belt because of the former world-class production of magnesite from the Stensgar Dolomite west of Chewelah. The Deer Trail is separated from the lower and middle Beltian rocks southeast of Chewelah by thrust faults (Stoffel and others, 1991). The Deer Trail Group most likely is the upper part of the Belt Supergroup (Miller and others, 1975; Miller and Whipple in Joseph, 1989).

Conventionally, the Three Sisters Formation, which is arkosic, pebbly, and Precambrian has been included in the Windermere Group of lithologically similar rocks (Stoffel and others, 1991). However, the Three Sisters is uncon-formable upon these rocks and grades conformably upward into the Gypsy Quartzite. Hence, the Three Sisters and Gypsy are part of the Sauk sequence (Fig. 5). Whichever datum ultimately is chosen as the Cambrian-Precambrian boundary, that boundary seems destined to be within the Sauk sequence.

Inspection of the map of Stoffel and others (1991) indicates that the major strati-graphic pattern in the North American sequences in northeastern Washington is that the uppermost Proterozoic Windermere sequence is progressively cut out to the southwest by the sub-Sauk unconformity. The metamorphic history of the North American sequences is poorly known: the Sauk and older sequences are in greenschist facies; whereas, the younger sequences appear to be unmetamorphosed. The major structural pattern is a series of northeasterly striking, northwesterly dipping thrusts that cause imbrication of the Proterozoic and Paleozoic sequences.

Magnesite mining in the Deer Trail Group fell victim to the electrolysis of sea water, which is now being displaced by the importation of Chinese rock. Uranium was mined from the Togo Formation of the Deer Trail Group at the Midnite mine about 50 km northwest of Spokane. Revett and St. Regis rocks have significant stratabound copper deposits in northwestern Montana and world-class Ag-Zn-Cu-Sb veins in the Coeur d'Alene district of northern Idaho; economic examples of these are still lacking in Washington.

The uppermost carbonate unit in the Sauk sequence has been the main producer in the state of lead and zinc (from metamorphosed Mississippi Valley-type deposits) in the Metalline Falls and Northport-Colville districts; mineralization is at least in part related to the sub-Tippecanoe unconformity. At Northport this carbonate unit is quarried for white dolomite. The glass sand operation at Valley is in the Addy quartzite of the Sauk sequence, and this quartzite also was used by Northwest Alloys to make ferrosilicon.

EASTERN ASSEMBLAGE

A belt dominated by Ordovician to Carboniferous pelitic rocks (but including some greenstone and chert) lies west of the Proterozoic to Paleozoic clastic and carbonate rocks indigenous to North America (Fig. 3). According to Smith (1991), this belt consists predominantly of three units. The Covada Group has an older Daisy sucession (dominantly thick-bedded, medium- to coarse-grained, poorly sorted subarkosic wacke and arenite with finer-grained interbeds) and a younger Butcher Mountain succession of pillow basalt, tuff, massive basalt, and limestone. Sparse paleontological evidence indicates that the Covada Group is middle to late Early Ordovician. The Bradeen Hill succession differs from the Covada Group in that it contains quartz-rich and feldspar-poor sandstone and abundant fine-grained strata. It contains chert pebble conglomerate with gritty, quartzofeldspathic clasts that seem to be derived from the Covada Group. The Bradeen Hill succession includes fine-grained shale, chert, chert-quartz sandstone, chert-pebble conglomerate, quartz arenite and minor volcanic rocks.

Megascopically most of the pelitic rocks of the eastern assemblage resemble the pelitic rocks of the Quesnel terrane to the west, but whereas the Quesnellian rocks are composed mostly of volcanic detritus, the Covada Group is subarkosic. The belt also has several bedded barite deposits, one of which north of Colville is Devonian. The Covada Group extends at least as far west as the southern part of the Republic graben (Fig. 3). The Covada Group is in thrust contact with broadly coeval North American mio-geoclinal rocks on the east. This boundary is the Huckleberry Ridge fault and the Columbia back thrust in Figure 3.

Because the original relation of the Covada Group and associated rocks to the North American rocks to the east and to the Quesnel terrane to the west remains somewhat uncertain, these rocks deserve a non¬committal name like "eastern assemblage." Originally these rocks were included in the Intermontane superterrane of the Canadian Cordillera. Terranes in this superterrane are believed to have been amalgamated by the end of the Triassic and to have accreted en masse to North America in mid-Jurassic (Monger and others, 1982). Because of its arkosic nature and because of the apparently similar ages of detrital zircons in these rocks to ages from the cratonic interior, the Covada Group, at least, now appears to be the distal marine portion of the North American miogeoclinal sequences to the east. In such a model, distal North American rocks were thrust onto the Paleozoic miogeoclinal rocks of the continent.

A counterpart of the eastern assemblage may be the Roberts Mountain allochthon and rocks of the Antler foredeep in Nevada (Fig. 2). The Roberts Mountain allochthon consists predominantly of oceanic Ordovician to Lower Mississippian strata, including numerous Devonian bedded barite deposits. The allochthon was emplaced eastward against North America during the Mississippian Antler orogeny and was overthrust from the west by the Golconda allochthon.

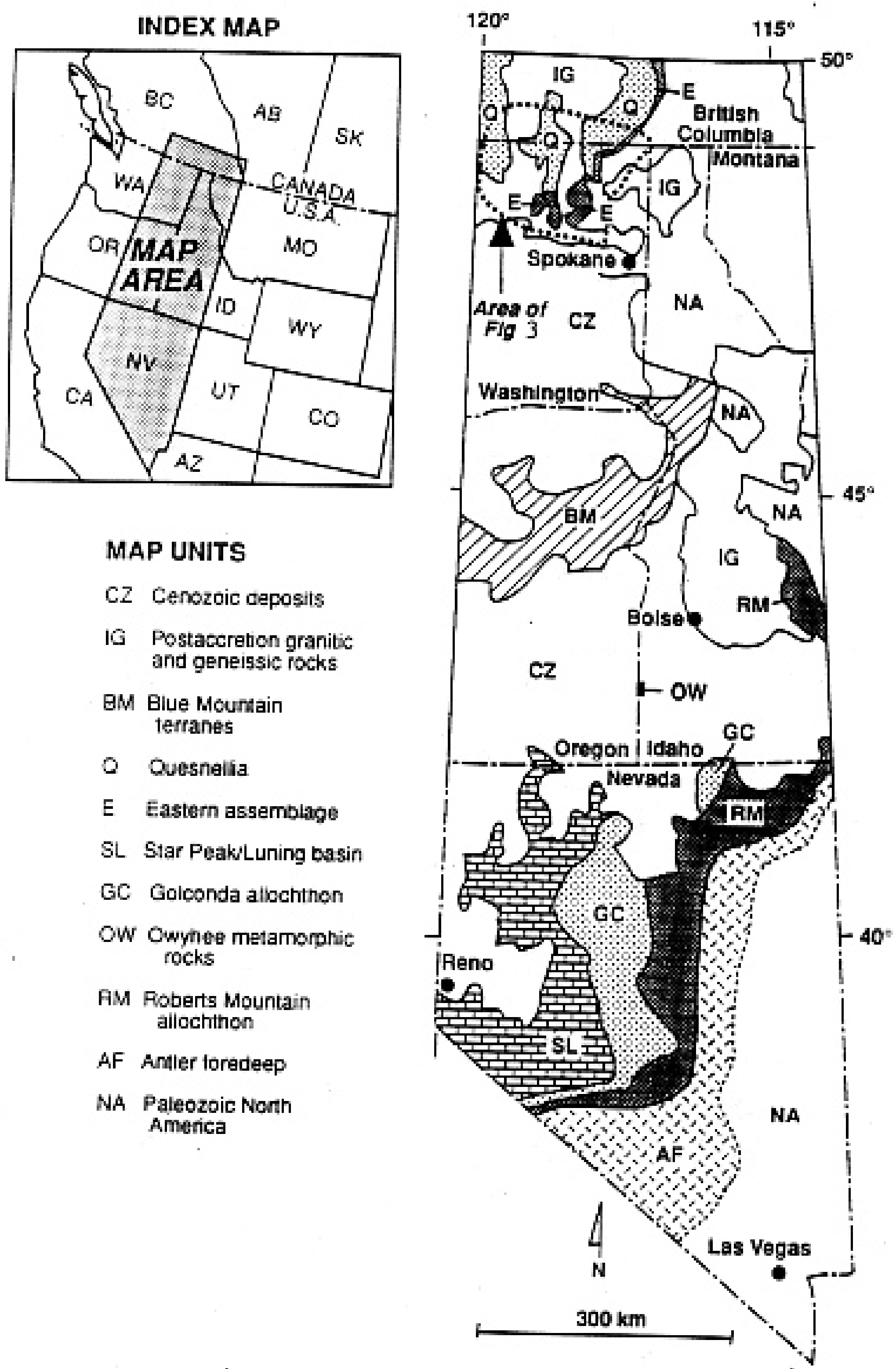


Figure 2. LITHOTECTONIC TERRANE MAP OF A PORTION OF THE NORTH AMERICAN CORDILLERA. Modified from Cheney and others, Fig. 1, in Lasmanis and Cheney (1993).

MAP UNITS

COVER SEQUENCES

Tw - Miocene to Pliocene Walpapi Sequence predominantly Columbia River Basalt Group
Tc - Eocene Challis Sequence
- Tcsi - Scatter Creek hypabyssal rocks
- Tcs - Sanpoil Formation, rhyodacitic
- Tco - O'Brien Creek Formation, arkosic

Z - Cretaceous Zuni Sequence Sophie Mountain Formation, conglomerate

PLUTONS

Ei - Eocene felsic plutons
Ji - Jurassic Shasket Creek alkalic plutons
Mi - Mesozoic felsic plutons
Mo - Mesozoic felsic orthogneisses

QUESNELLIA

Mu - Mesozoic rocks, undivided
Jr - Jurassic Rossland Group
- Jrh - Hall Formation, argillite
- Jre - Elise Formation, mafic volcanic rocks, Jref - felsite
- Jra - Archibald Formation, argillite

Trb - Triassic Brooklyn Formation
Pu - Carboniferous to Permian western assemblage, Knob Hill and Attwood Groups, undivided
- Pa - Attwood Group, undivided
  Pap - pelitic phyllite, Paa - argillite, Paf - felsic volcanic and volcaniclastic rocks, Pac - carbonate rocks
- Pk - Knob Hill Group, undivided
  Pkg - Palmer Mountain greenstone, um - ultramafic rocks and listwanite

SOUTHWESTERN METAMORPHIC BELT

Mom - Mesozoic(?) megacrysic orthogneiss
hmg - Mesozoic(?) pelitic gneiss
hmp - Mesozoic(?) pelitic phyllite
swm - Mesozoic(?) paragneiss and orthogneiss

EASTERN ASSEMBLAGE

OCe - Ordovician to Carboniferous undivided, mostly pelitic rocks, including Ordovician Covada Group

METAMORPHIC CORE COMPLEXES

Ei - Eocene felsic plutons
Mi - Mesozoic felsic plutons
hmt - Mesozoic Tonasket orthogneiss
hm - metamorphic rocks, undivided
hmm - Tenas Mary Creek assemblage, Cretaceous orthogneiss and Proterozoic and Paleozoic paragneisses

METAMORPHIC ROCKS

hmu - rocks of unknown age and origin

FAULTS

high angle fault

detachment fault (ticks on upper plate)

thrust fault (sawteeth on upper plate)

abbreviations of names

BCF - Bacon Creek fault
BMF - Bodie Mountain fault
CMF - Cayuse Mountain fault
CLF - Columbia fault
CF - Chesaw Fault
DMF - Dunn Mountain fault
EMF - Eagle Mountain fault
GDF - Gold Drop fault
GRF - Granby River fault
GWF - Greenwood fault
HRF - Huckleberry Ridge fault
KRF - Kettle River fault
LCF - Lind Creek fault
LMF - Lambert Creek fault
MAF - Mount Attwood fault
MCF - Myers Creek fault
MWF - Mount Wright fault
No. 7F - Number 7 fault
OF - Okanogan fault
OLF - Omak Lake fault
RF - Rossland fault
SCF - Salmon Creek fault
SF - Sherman fault
SKF - Scatter Creek fault
SLF - Slocan Lake fault
SNF - Snowshoe fault
TMF - Thimble Mountain fault
VS - Valkyr shear zone
WF - Waneta fault
WMF - White Mountain fault

FOLDS

upright overturned

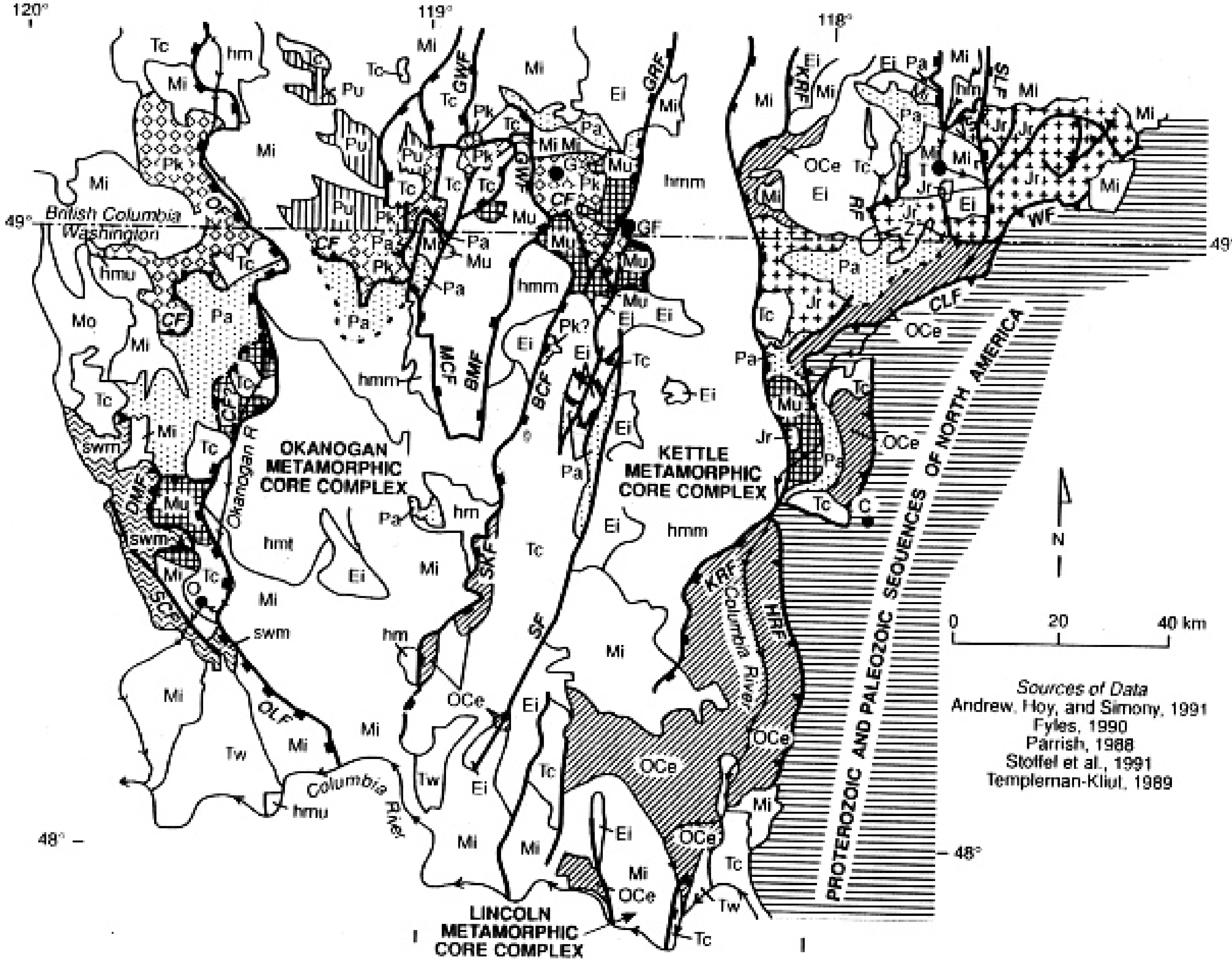
antiform

TOWNS

abbreviations of names

C - Colville
G - Greenwood
GF - Grand Forks
O - Omak
R - Republic
T - Trail

Figure 3. REGIONAL GEOLOGIC MAP OF THE SOUTHERN PART OF QUESNELLIA AND BOUNDING UNITS. Cheney and others, Fig. 2, in Lasmanis and Cheney (1993). The explanation to this figure also applies to Figures 7, 14, 15, and 16. This explanation is Table 1 of Cheney and others in Lasmanis and Cheney (1993).


120°
119°
118°
49°
48°
British Columbia
Washington
Okanogan R
Columbia River
OKANOGAN METAMORPHIC CORE COMPLEX
KETTLE METAMORPHIC CORE COMPLEX
LINCOLN METAMORPHIC CORE COMPLEX
PROTEROZOIC AND PALEOZOIC SEQUENCES OF NORTH AMERICA
N
0 20 40 km
Sources of Data
Andrew, Hoy, and Simony, 1991
Fyles, 1990
Parrish, 1988
Stoffel et al., 1991
Templeman-Kluit, 1989

SEQUENCE	LITHOLOGY	FORMATIONAL OR GROUP NAMES: SOUTH OF 48°30'	NORTH OF 48°30'	SOUTHERN B.C.
TIPPE-CANOE	ARGILLITE	LEDBETTER	LEDBETTER	ACTIVE
SAUK	CARBONATE	OLD DOMINION	METALLINE	NELWAY
	ARGILLITE	MAITLEN	MAITLEN	LIAB
	QUARTZITE	ADDY	GYPSY	RENO & QUARTZITE RANGES
	QUARTZITE & ARKOSIC CONGLOMERATE	NOT PRESENT	THREE SISTERS	THREE SISTERS
W	ARGILLITE	MONK	MONK	MONK
	GREENSTONE	HUCKLEBERRY	LEOLA	IRENE
	CONGLOMERATE (TILLITE)	HUCKLEBERRY CONGLOMERATE	SHEDROOF	TOBY
B	LARGELY CLASTIC	DEER TRAIL & BELT GROUPS	PRIEST RIVER & BELT GROUPS	PURCELL SUPERGROUP

Figure 4. SYNONYMOUS NAMES FOR THE LITHOSTRATIGRAPﬃC UNITS OF VARIOUS SEQUENCES IN NORTHEASTERN WASHINGTON AND ADJACENT BRITISH COLUMBIA.

Yet another set of names for most units occurs farther north in British Columbia.

QUESNELLIA

The Quesnel terrane (or Quesnellia) is west of the eastern assemblage. If the eastern assemblage is a distal portion of North America or a separate terrane, Quesnellia is the easternmost terrane of the Intermontane superterrane. The discussion that follows is a condensation of Cheney and others in Lasmanis and Cheney (1993).

Quesnellia has three unconformity-bounded sequences. The lithostratigraphic names in the middle column of Figure 6 are from southernmost British Columbia; they have precedence over the synonyms, which are used in Washington. The Knob Hill (Kobau) rocks are dominated by variably phyllitic greenstones, but include chert, the Palmer Mountain dioritic to gabbroic greenstone, and ultramafic rocks . Some of the ultramafic rocks are now magnesite-dolomite-quartz rocks called listwanites. The Knob Hill rocks were originally thought to be unconformable upon the pelitic Attwood (Anarchist) rocks, but the presence of listwanites, ultramafic rocks, and tectonic features along this contact show that it is tectonic (the Chesaw thrust). Because this contact is tectonic not strati-graphic, the term "western assemblage" is used here as a collective term for the Carboniferous to Permian ophiolitic and pelitic rocks. Relations near the Overlook gold mine northeast of Republic suggest that the ophiolitic (Knob Hill) rocks stratigraphically underlie the pelitic (Attwood) rocks.

The middle Triassic Brooklyn Formation (predominantly clastic and carbonate rocks) is unconformable upon both the pelitic and ophiolitic rocks of the western assemblage; thus, the ophiolitic and pelitic rocks must have been adjacent to each other (amalgamated) in pre-Brooklyn time. The Jurassic Rossland Group uncon-formably overlies both the western assemblage and the Brooklyn Formation. Near Omak the Cave Mountain Formation, dominated by carbonate rocks and capped by phyllitic greenstone, is most likely a composite of the Brooklyn Formation and the

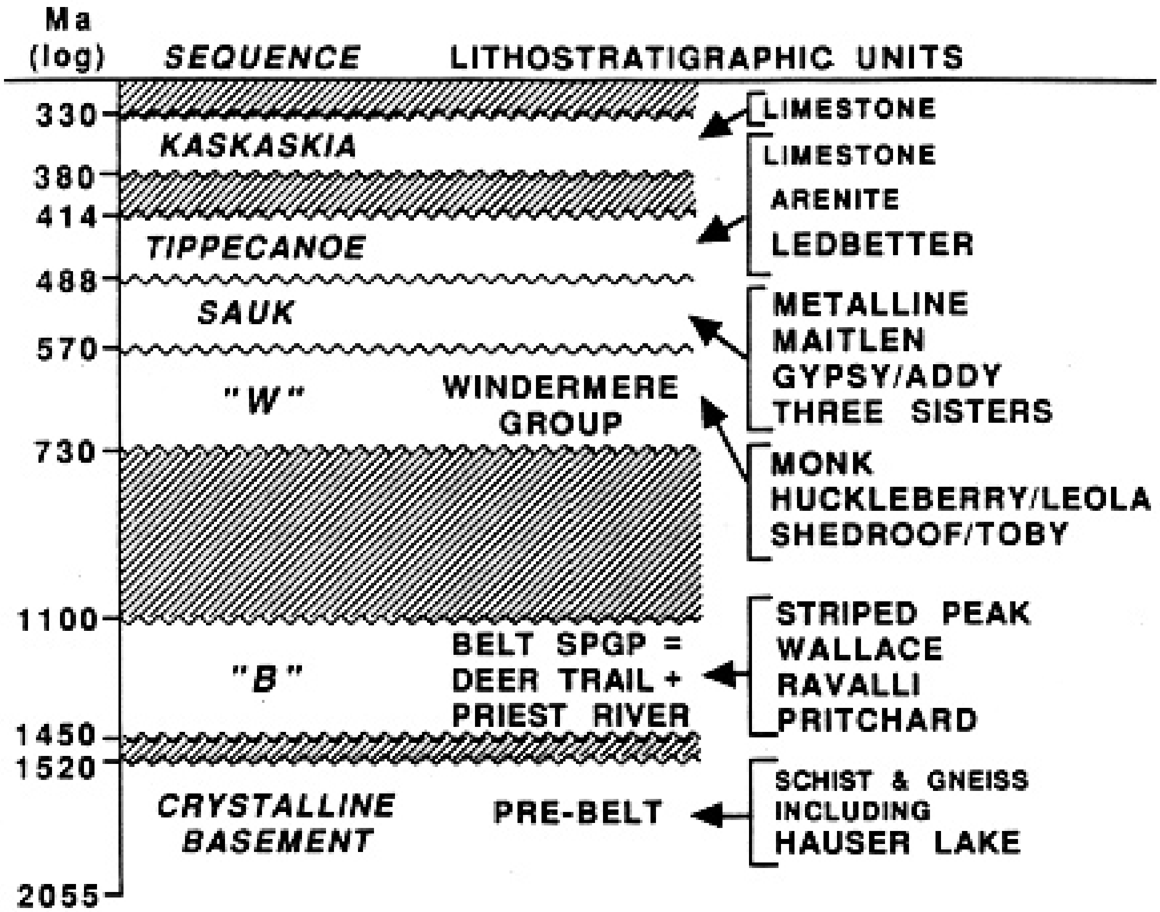


Figure 5. SEQUENCE STRATIGRAPHY OF THE NORTH AMERICAN ROCKS IN NORTHEASTERN WASHINGTON. Note that the time scale is logarithmic. See text for the lithostratigraphic position of the Deer Trail Group and the Three Sisters Formation.

Rossland Group.

All of the Quesnellian rocks are cut by a major thrust, the Chesaw fault, which extends discontinuously from Omak, Washington to Grand Forks, British Columbia (Fig. 3). The Chesaw fault may be related to the mid-Jurassic docking of Quesnellia with North America. The Loo mis pluton (Fig. 7) with a discordant K/Ar date on hornblende of 194 ± 6 Ma, appears to cut the Chesaw thrust. The 164 to 169 Ma Nelson plutons intrude both Quesnellian and North American rocks, thereby providing a minimum date for the accretion of Quesnellia.

All of the Quesnellian sequences are in greenschist facies and all are known to have large recumbent folds. The ages of these folds and other structural features with respect to the age of the Chesaw fault are largely unresolved. The Chesaw thrust is folded by large upright folds such as the one southwest of Oroville (Fig. 7). Figure 2 shows that the eastern assemblage of Quesnellia as equivalent to the Golconda allochthon of Nevada. The Mesozoic rocks of Quesnellia most likely are correlative with the Mesozoic carbonate and volcanic rocks of the Star Peak/Luning basins of northwestern Nevada.

The gold deposit at the Overlook mine northeast of Republic is in Attwood (Anarchist) rocks and is associated with a volcanogenic massive sulfide and iron formation. During 1993 permits are being sought to start the Crown Jewel open-pit gold mine in a skarn in Attwood rocks east of Chesaw. Numerous quartz veins in and adjacent to various plutons were mined in the past for gold, especially near Oroville.

SOUTHWESTERN METAMORPHIC BELT

A belt of amphibolite-facies paragneiss and orthogneiss bounds the Quesnellian rocks on the southwest near Omak (Figs. 3 and 7). This southeasterly striking belt continues southeast of the Okanogan River (Atwater and others, 1984), and the map of Stoffel and others (1991) implies that it could extend beneath the Columbia River Basalt Group to Grand Coulee. If so, this is a spatially important and extensive belt. To the west the belt is intruded by a variety of Mesozoic (mostly Cretaceous) unfoliated to moderately foliated granitic plutons of the Okanogan Range. These plutonic rocks are truncated by the Chewak-Pasayten fault, which bounds the Jurassic to Cretaceous sedimentary and volcanic rocks preserved in the Methow valley. On the southeastern margin of the Methow valley, the Cretaceous granitic plutons of the Okanogan Range intrude the amphibolite-facies Leecher metamorphic rocks, which might be correlative with the metamorphic rocks near Omak. The following

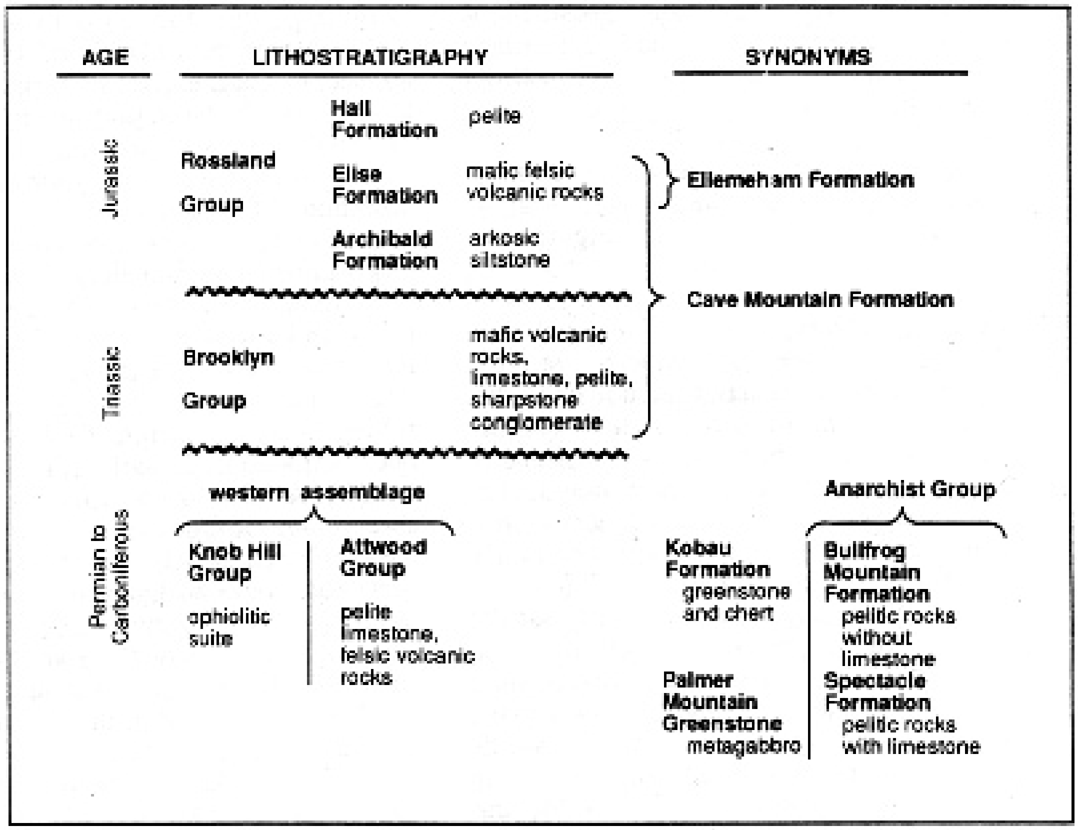


Figure 6. UNCONFORMITY BOUNDED SEQUENCES OF QUESNELLIA. Cheney and others, Fig. 3, in Lasmanis and Cheney (1993). The vertical line illustrates that coeval units are tectonically juxtaposed (by the Chesaw fault).

descrip¬tion of the southwestern metamorphic belt in the area of Figure 7 is summarized from Cheney and others in Lasmanis and Cheney (1993).

Although fine-grained pelitic paragneiss is the most common lithology in the southwestern metamorphic belt, the most distinctive rocks are orthogneisses. One is the hornblende- and biotite-bearing and feldspar megacrystic Leader Mountain Gneiss (Mom in Fig. 7). East of the Okanogan River the porphyritic granodiorite of Omak Lake of Atwater and others (1984) is megascopically similar to Mom. Mom has several percent potassium feldspar megacrysts up to 8 cm, and the hornblende is ferrohastingsite (which is a distinctive blue green in thin section). Significantly, Mom does not occur in Quesnellian rocks. A U/Pb date on zircon should soon resolve the age of Mom and the southwestern metamorphic belt.

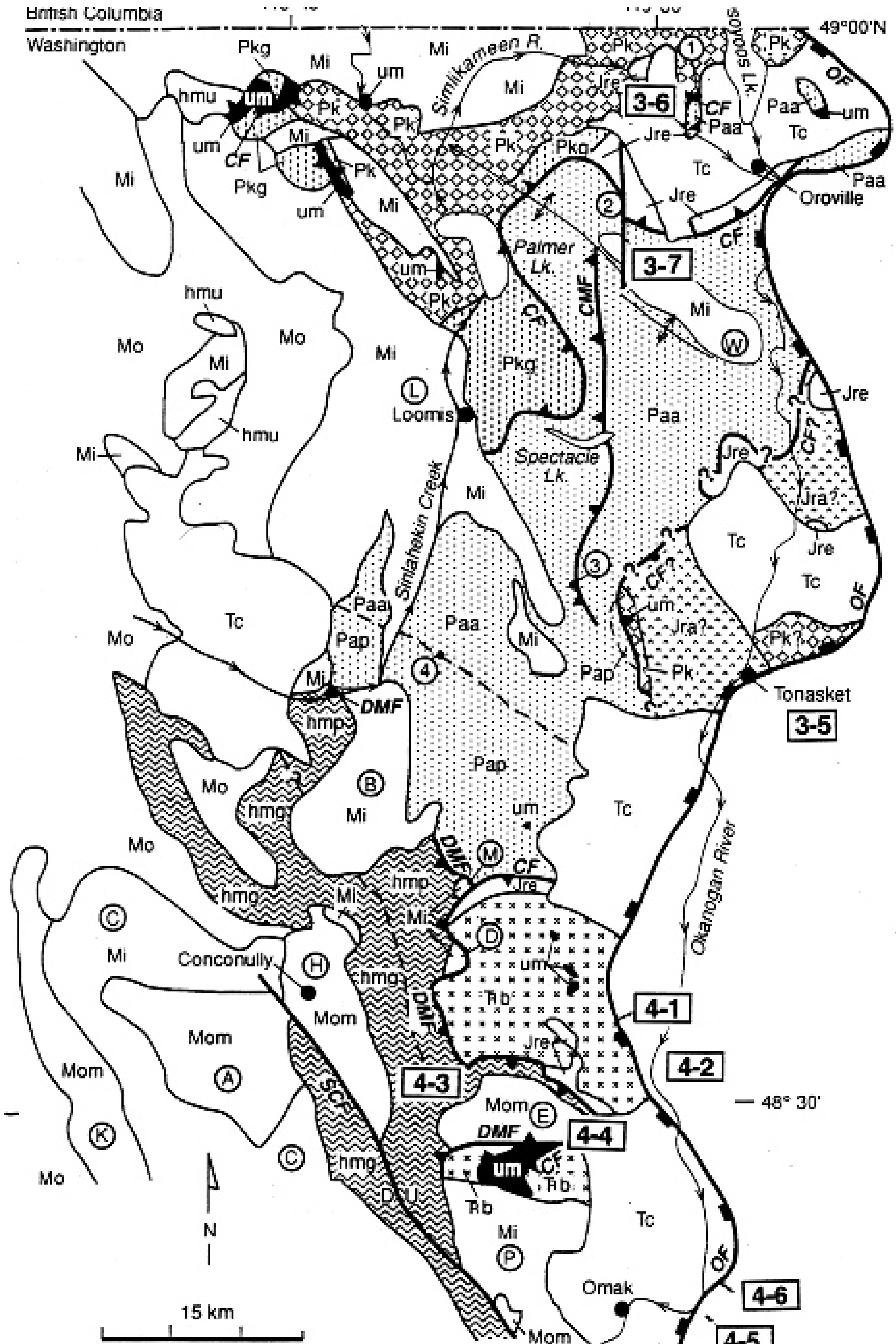
The metamorphic discontinuity between the amphibolite-facies southwestern metamorphic belt and greenschist facies rocks of Quesnellia has been difficult to recognize. The pelitic rocks of the western assemblage of Quesnellia become more phyllitic south-westward and the pelitic paragneisses of the southwestern metamorphic belt become more phyllitic northeastward (Fig. 7). The metamorphic discontinuity between the two is the Dunn Mountain fault; at Dunn Mountain, the southwestern metamorphic belt is thrust over the Cave Mountain Formation (Brooklyn Formation and Rossland Group). If the southwestern metamorphic belt extends as far southeast as Grand Coulee, it also truncates the Covada Formation of the eastern assemblage.

POST-ACCRETIONARY NORTH AMERICAN SEQUENCES

Figure 1 indicates that five North American unconformity-bounded se¬quences post-date accretion of the Intermontane superterrane. Only the Zuni, Challis, and Walpapi occur in northeastern Washington; the Challis is the most extensive. The Zuni is restricted to a few tiny remnants (Fig. 3) of conglomerate of the Cretaceous (Cenomanian to Campanian) Sophie Mountain Formation, which is unconformable upon Quesnellian rocks (Little, 1982) along the International Border between the Columbia and Kettle rivers (Fig. 3).

The Challis sequence consists of middle Eocene sedimentary,

Figure 7. (facing page)
GEOLOGIC MAP OF THE OKANOGAN VALLEY. Modified from Cheney and others, Fig. 6 in Lasmanis and Cheney (1993). The explanation for Fig. 3 is also the explanation for this figure. The dashed lines mark the gradation of argillite of the western assemblage (Paa) into phyllite (Pap) and of paragneiss of the southwestern metamorphic belt (hmg) into phyllite (hmp).
Plutons (circled) are: A, Mineral Hill phase of the Conconully pluton; B, Blue Goat; C, Conconully; D, Dunn Mountain; E, Evans Lake; H, Happy Hill; K, Leader Mountain; L, Loomis; M, Mud Lake; P, Pogue Mountain; W, Whiskey Mountain. Localities (circled) of felsic metavolcanic rocks in the Attwood Group are 1, Hot Lake; 2, Hicks Canyon; 3, Silver Mountain mine; 4, Lemansky


British Columbia
Washington
49°00'N
Similkameen R.
Osoyoos Lk.
Pkg
Pk
Mi
um
hmu
CF
OF
Paa
Tc
Jre
3-6
Oroville
Palmer Lk.
CMF
3-7
Pkg
Mo
Loomis
Spectacle Lk.
Sinlahekin Creek
Jra?
CF?
Pk?
Pap
DMF
hmp
hmg
Tonasket
3-5
Okanogan River
Conconully
Mom
Rb
4-1
4-2
4-3
4-4
4-5
4-6
48° 30'
SCF
Omak
N
15 km

volcaniclastic, and volcanic rocks. These rocks are commonly regarded as having been deposited in a number of local grabens, such as the Republic graben, but Pearson and Obradovich (1977) showed that the same lithostratigraphic units occur in a number of grabens (Fig. 8). Although Pearson and Obradovich did not subdivide the rocks into unconformity-bounded sequences, Cheney in Lasmanis and Cheney (1993) did (Fig. 9). He correlated these sequences across northeastern and central Washington and concluded that the sequences (as opposed to individual lithostratigraphic units) originally must have been virtually continuous across Washington. The geographic conti¬nuity of these sequences was destroyed by intra-Challis and later unconformities and by faults; remnants of the sequences are now preserved in numerous structural lows. Representatives of these sequences exist in southern British Columbia, western and north-central Oregon, Nevada, southwestern Montana, and the Great Plains.

The major mine in the Challis sequence in northeastern Washington is the epither-mal gold/silver Knob Hill mine at Republic; it has been in continuous operation since the late 1930s and has recovered more than 2.2 million ounces of gold and several times more silver. The epithermal gold/silver district in central Washington at Wenatchee also is in Challis rocks, and, like Republic, is fairly unusual in that the major gold minerals are selenides. The Challis-aged molybdenum-copper deposit at Keller (south of Republic) seems to be the most nearly economic of the porphyry Cu/Mo prospects. A sandstone-type uranium deposit was mined in Challis arkosic rocks at the Sherwood mine about 50 km northwest of Spokane.

The most voluminous lithostratigraphic unit of the Walpapi sequence in eastern Washington is the Columbia River Basalt Group (CRBG). The following summary is condensed from a review by Cheney in Lasmanis and Cheney (1993). Sources of most of the CRBG were northwesterly trending dikes in adjacent parts of Washington, Oregon, and Idaho. These dikes probably were related to rifting dur¬ing development of the Basin and Range Province and may be the product of a plume in the mantle that has migrated east¬ward as the Yellowstone hotspot.

The two basal units of the CRBG, the Imnaha and Grande Ronde Basalts, com¬prise the bulk of the CRBG and were extruded between 17.3 and 15.6 Ma. Not only do a number of unconformities occur within the CRBG, the basalts are arched over the Cascade Range (which is particu¬larly obvious at Mission Ridge south of Wenatchee, Washington). Thus, the original volume and extent of the CRBG has been reduced (probably significantly), and the present topography of the Cascade Range is a post-2 Ma feature.

No significant metallic mineral production has been recorded from the Walpapi sequence in Washington. Felsic volcanic rocks younger than CRBG do host epithermal precious metal and mercury deposits in Nevada, Idaho, and Oregon, but these rocks are unknown in northeastern Washington.

METAMORPHIC CORE COMPLEXES

The metamorphic core complexes (MCC) of Washington (and adjacent British Columbia and Idaho) formed during Challis time. They are the most prominent structural and topographic features of northeastern Washington. The following description is summarized from Orr and Cheney in Schuster (1987), Ross (1991), and Cheney in Lasmanis and Cheney (1993).

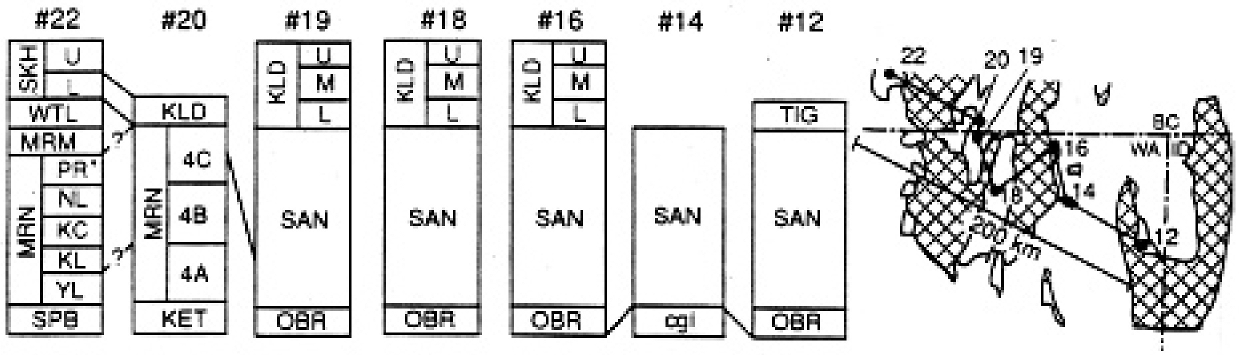
The MCCs have two essential features: (1) they consist of amphibolite-facies metamorphic rocks and Eocene granitic plutons, and (2) their margins (except where truncated by later high-angle faults or overlain by the Walpapi sequence) are bounded by low-angle, normal faults (detachment faults). These faults consist 0 to 4 km of mylonitic rocks in amphibolite to greenschist facies capped by cataclastic rocks in greenschist or lower facies. Because the cataclastic rocks rarely are more than a hundred meters thick and are easily eroded, they rarely crop out in northeastern Washington.

The map of Stoffel and others (1991) shows that detachment faults cut all of the previously described regional units except the Zuni sequence (too areally restricted) and the Walpapi sequence (too young). Cooling ages within the crystalline rocks of the MCCs, ages of dikes within the detachment faults, and cross cutting relations of the detachment faults (Parrish and others, 1988) show that final development of the MCCs postdates the Klondike Mountain and Tiger Formations, the two youngest Challis formations in northeastern Washington.

As shown by Figure 3, many of the bounding faults of the Tertiary grabens are detachment faults. Most of the Tertiary rocks are, therefore, synformally preserved between MCCs or on the limbs of roll-over anticlines (effectively, half-synclines) adjacent to individual MCCs. The detachment faults record significant middle-Eocene extension of the crystalline basement beneath a cover consisting of the Proterozoic to Eocene North American sequences, the eastern assemblage, Quesnellia, and the southwestern metamorphic belt. Cumulative extension is believed to be 25 to 30% (Parrish and others, 1988), and considerably more locally. Therefore, Challis successions now bounded by detachment faults may once have been considerably closer together, or even contiguous (Parrish and others, 1988).

The Kettle MCC and the northeastern-most arm of the Okanogan MCC have a distinctive succession of metamorphic rocks, known as the Tenas Mary Creek (TMC) assemblage (Orr and Cheney in Schuster, 1987; Stoffel and others, 1991-). The orthogneisses within the TMC are Cretaceous (Armstrong and others in Schuster, 1987; Armstrong and others in Ross, 1991). A feldspathic quartzite up to 650 m thick in the TMC defines the broadly domal pattern of the Kettle MCC in Washington, but north of the International Border thinner and structurally lower quartzite and paragneiss occur.

The thick upper quartzite has some 570 to 674 Ga zircons (Ross and Parrish in Ross, 1991), whereas, the structur-



A PORTION OF THE CORRELATION DIAGRAM OF PEARSON AND OBRADOVICH.(1977, FIG. 3) FOR EOCENE ROCKS IN NORTH-EASTERN WASHINGTON AND ADJACENT BRITISH COLUMBIA.
The location of each column is shown on the accompanying map. Abbreviations for formations are the same as those used in Fig. 9 with the following exceptions: cgl, conglomerate without volcanic clasts, probably in part correlative with the O'Brien Creek Formation; KET is Kettle River Formation; members of the Marron Formation are KC (Kearns Creek), KL (Kitley Lake), NL (Nimpit Lake), PR (Park Rill), WL (White Lake), and YL (Yellow Lake); 4A, 4B, and 4C are divisions of the Marron formation; L, M, and U are the lower, middle, and upper members of the Klondike Mountain Formation.

ally lower rocks have a variety of dates that suggest an age of 1.7 to 1.9 Ga; therefore, a major unconformity probably exists below the thick quartzite (Armstrong and others in Ross, 1991). Although Ross and Parrish favored correlation of the thick quartzite with the Gypsy of the Sauk sequence, the feldspathic nature of the quartzite suggests that it may be more akin to the Three Sisters Quartzite. The ages of zircons in the Three Sisters, Gypsy, and Winder-mere Group, a North American source for the 570 to 674 zircons, and any similarity to the TMC parag-neisses to the Sauk or other North American sequences are still unknown; thus the assertion of Armstrong and others in Ross (1991) that the burden of proof now lies with those who would propose an accretionary origin for the paragneisses of the Kettle and Okanogan MCC seems premature. If the MCCs represent North American crystalline basement, the apparent maximum amount of obduction of Quesnellia and of the eastern assem-blage (125 km along the International Border) must be reduced by at least 25 to 30% due to mid-Eocene extension.

No significant metallic mineral production has been recorded from the MCCs. A minor amount of uranium was recovered from the Priest River MCC north of Spokane in the 1950s, and sub-economic radioactive pegmatites in the Kettle and Okano-gan MCC teased prospectors in the 1950s and 1970s. The my-lonitic eastern quartzite of the Kettle MCC retails for $350/ton as patio rock in Seattle. A high-calcium marble deposit in the Okanogan MCC north of Waconda was brought into production several years ago.

SUMMARY

This field trip traverses the Proterozoic to Paleozoic miogeo-clinal trailing edge of North America, accreted terranes to the west, and post-accretionary cover sequences. The Proterozoic to Paleozoic North American rocks are much thicker than their counterparts in the cratonic interior to the east. The metasedi-mentary, am-phibolite-facies rocks of the metamorphic core complexes may be the western edge of the pre-1.5 Ga North American crystalline basement. The Intermontane super-terrane accreted in mid-Jurassic. The Insular, Northwest Cascades, and Coast Range su-perterranes accreted outboard of the Intermontane superterrane. The Challis sequence is the most extensive of three cover sequences in northeast-ern Washington. Units in this sequence formed as regional prisms on the edge of North America prior to, and probably until, docking of the Coast Range superterrane. Mid-Eocene crustal extension formed the metamorphic core complexes and segmented the regional outcrop patterns of all older regional units.

The Columbia River Basalt Group of the Walpapi sequence unconformably overlies all of the other regional units. All of the regional units in northeastern Washington also occur beyond the state.

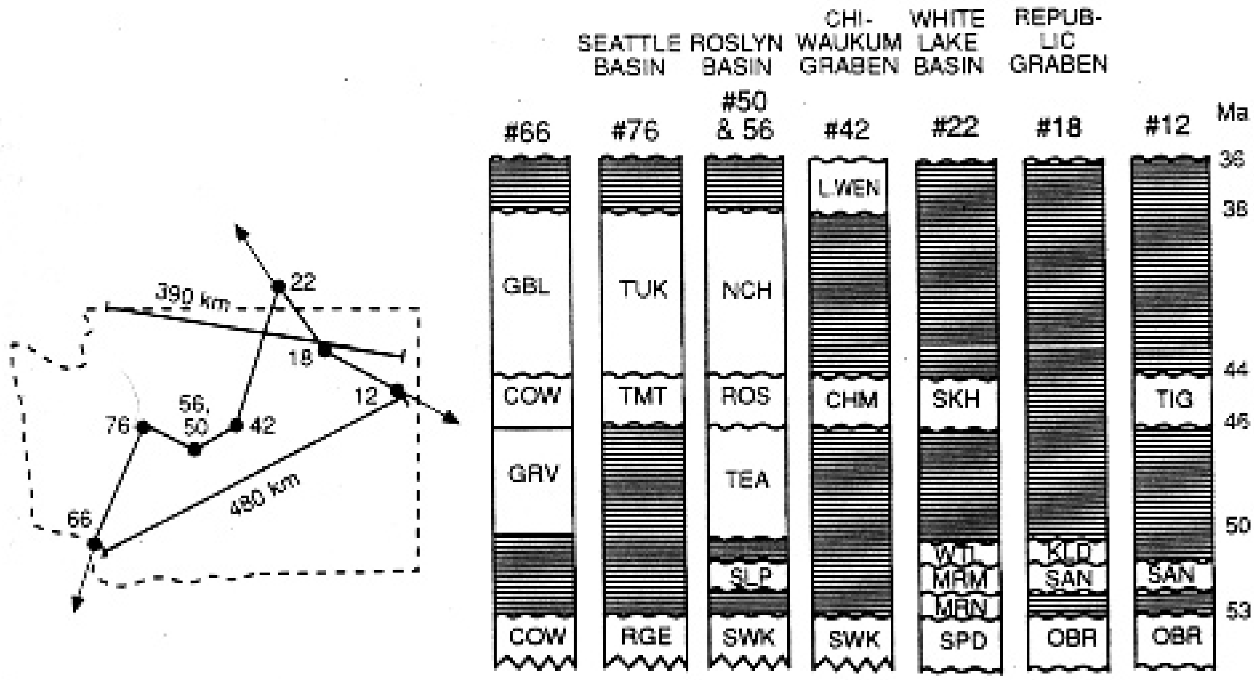


Figure 9. REGIONAL SEQUENCES WITHIN THE CHALLIS SEQUENCE IN WASHINGTON.
Cheney, Fig. 10, in Lasmanis and Cheney (1993). The location of each column is shown on the accompanying map. Note that columns 12, 18, and 22 also occur in Fig. 8. See Cheney in Lasmanis and Cheney (1993) for sources of data. Wavy lines are unconformities, straight lines indicate that no local evidence for an unconformity is yet known; saw teeth indicate that the bottom of the formation is not exposed. Closely spaced horizontal lines illustrate a gap in the lithostratigraphic record.
Starting from the base upward, the O'Brien Creek Formation (OBR) and correlatives are arkosic and tuffaceous; Marron (MRN) is alkalic volcanic rocks; Sanpoil (SAN) and correlatives are felsic volcanic rocks; Klondike Mountain (KLD) is felsic volcanic and volcaniclastic rocks; Teanaway (TEA) and correlative are andesitic to basaltic volcanic rocks; Tiger (TIG) and correlatives are arkosic; Naches (NCH) and correlatives are interbedded arkosic rocks, felsic volcanic rocks, and basaltic volcanic rocks; Lower Wenatchee (L. WEN) is arkosic.

Abbreviations for formations:
CHM, Chumstick Formation COW, Cowlitz Formation GBL, Goble Volcanics GRV, Grays River volcanic rocks of the Cowlitz Formation KLD, Klondike Mountain Formation L WEN, Lower member of the Wenatchee Formation MRM, Marama Formation MRN, Marron Formation NCH, Naches Formation OBR, O'Brien Creek Formation

RGE, Raging River Formation ROS, Roslyn Formation SAN, Sanpoil Volcanics SKH, Skaha Formation SLP, Silver Pass volcanic rocks SPB, Springbrook Formation SWK, Swauk Formation TEA, Teanaway Formation TIG, Tiger Formation TMT, Tiger Mountain Formation TUK, Tukwila Formation WTL, White Lake Formation

ROAD LOG

INTRODUCTION

Beginning with Day Two, this road log lists cumulative mileage (and mileages between important features). As a note of caution, these mileages may be up to 3% too long.

DAY ONE: SEATTLE TO DEER LAKE

- From Seattle take SR 520 east over the Evergreen Point Bridge. (Gov. A. D. Rosellini Bridge.)
- Take 1-405 north toward Everett.
- At Woodinville take SR 522 east to Wenatchee and Monroe.
- In Monroe, take US 2 east to Wenatchee.
- Stop in Wenatchee (about 3 hours after leaving Seattle) near the Grand Valley Shopping Center where various restaurants are available. Report back to the vehicles in one hour.
- Return to US 2 and proceed east toward Spo kane.
- At Reardon, turn left (north) on SR 231 toward Colville.
- At Springdale, turn right on SR 292 toward US 395 and Spokane.
- Pass the town of Loon Lake and at US 395, turn left (north).
- 3.3 Miles north of the junction of US 395 and SR 292, turn right (east) on Deer Lake North Road.

END OF DAY ONE

DAY TWO: DEER LAKE TO REPUBLIC

This road log starts at the intersection of Deer Lake North Road and US 395. This junction is about mile 193.7 on US 395 and is approximately

a) 35 miles north of Spokane on US 395,

b) 3.3 miles north of the intersection of US 395 and SR 292,

c) 35 miles south of Colville on US 395,

d) 13.9 miles south of Chewelah on US 395, and

e) 325 miles east of Seattle via SR 520,1-405, SR 522, US 2, SR 231, SR 292, and US 395.

0.0 (0.0) Intersection of Deer Lake North Road and US 395.

1.9 (1.9) Stay left (north) at fork in road and drive along the northwest shore of Deer Lake.

2.2 (0.3) Pinelow Park (private campground).

2.7 (0.5) Camp Clifford, Salvation Army.

5.2 (2.5) End of pavement and end of northeast arm of Deer Lake. Vehicles can turn around here or at a junction another 1/2 mile northeast and will wait for us 0.5 miles southwest of here at the end of the traverse.

STOP 2-1: BURKE AND REVETT FORMATIONS OF THE BELT SUPERGROUP

Belt geologists use the following field terms: quartzite if the rock is unscratch-able, siltite if slightly scratchable, and argillite of easily scratchable. All three occur on this traverse. Figure 10 is a guide for Stops 2-1 and 2-2. Walk southwest along the road for 0.5 miles, proceeding up-section from the Burke Formation into the Revett Formation. Miller and Clark (1975) stress that characteristics of these formations are similar here and in northern Idaho.

The same lithologies occur in both formations, the Burke being thinner bedded, less quartzitic, more intricately folded, and better cleaved. Quartzites in both formations are rusty weathering, well sorted, fine grained, and gray with mm- and cm-scale plane laminations. The Burke has 1/3 m-scale bedding compared to predominantly m-scale layering in the Revett. Because of the greater abundance of siltites and argillite, the Burke has more visible mus-covitic argillite (some with mud chips and interference and symmetrical ripples), small scale folding, and cleavage, but has fewer mm- to m-scale quartz veins. Note that significant portions of the Revett are cov¬ered (and likely to contain argillites and siltites). Continue southwest toward US 395

6.9 (1.7) Pull out on right.

STOP 2-2: ST. REGIS FORMATION

Again, Miller and Clark (1975) stress that the St. Regis Formation is similar to its occurrences in northern Idaho. Here it consists of rusty weathering, laminated argillite and minor siltite in beds only a few cm thick. Although much of the rock is green or gray, some is pale purple. Mud chips are most noticeable in the purple rocks.

Return to US 395.

Figure 10 GEOLOGY OF THE DEER LAKE AREA.

This figure is a portion of Miller and others, 1975, Plate 2. Units are:

Qag, undifferentiated Quaternary deposits
Tm, Tertiary mafic dikes
Kc and Km, granitic rocks
Ca, Addy Quartzite
pCwu, upper part of the Wallace Formation
pCwl, lower part of the Wallace Formation
pCsr, St. Regis Formation
pCr, Revett Formation
pCb, Burke Formation
pCp, Pritchard Formation

10.5 (3.6) Junction of Deer Lake North Road and US 395, turn right (north) on 395 toward Colville and Chewelah.

24.4 (13.9) Traffic light in Chewelah on US 395.

30.0 (5.6) Junction of Blue Creek Road and US 395, turn right (west) on Blue Creek Road.

30.4 (0.4) Turn left (south) on Dry Creek Road.

30.9 (0.5) Intersection of Dry Creek road and Duncan Road. Vehicles can turn around here. Walk 0.1 miles south on Dry Creek Road to Stop 2-3.

STOP 2-3: HUCKLEBERRY "CONGLOMERATE"

Although this outcrop appears underwhelming, it represents an important but discontinuous unit at the base of the Windermere Group. Here the rock is a phyllitic, poorly sorted, sandstone. Some of the flattened clasts are nearly 1 cm long. Note that the clasts are polymictic and some are quartz, which serves to separate this rock from the overlying Huckleberry greenstone, with which the conglomerate has been lumped.

Elsewhere in Washington and southern BC, this unit is the Shedroof conglomerate and the Toby conglomerate, respectively (Fig. 4). These cobble conglomerates are unsorted, unstratified, and polymictic. Diamictites of this age are known on a few continents and, increasingly, are considered to be latest Proterozoic tillites and possible worldwide chronostratigraphic (marker) units.

Notice the suspended mining operations in the Addy quartzite in the hills to the northeast. This was for the ferrosilicon plant at Addy.

Return to the intersection of Blue Creek Road and US 395.

31.8 (0.9) Intersection of Blue Creek Road and US 395.

STOP 2-4: HUCKLEBERRY GREENSTONE

This fine-grained greenstone varies from nearly massive to slightly phyllitic. Epidote, calcite, and chlorite can be seen. Dark mottles on foliation surfaces and rare black phyllitic clasts > 1 cm imply that some of the greenstone was volcaniclastic. However, some lensoid features may be deformed pillows. Note that discontinuous quartz veins at the south end of the outcrop have various cataclastic features, a fairly common feature of quartz veins (especially auriferous ones) in greenstone. Because it dips steeply to the north, the Huckleberry greenstone structurally overlies the younger Addy quartzite. Continue north on US 395 toward Addy and Colville.

34.3 (2.5) Turn left (west) off US 395 to Addy.

34.5 (0.2) Addy, turn left crossing railroad tracks and river and follow the road south around the ridge.

35.0 (0.5) Stop 2-5 is behind fence to the north; continue west.

35.5 (0.5) Marble Valley Road, turn left (north).

35.9 (0.4) Turn into main gate of Northwest Alloys.

36.1 (0.2) Main gate of Northwest Alloys. Mr. Ozzie Wilkenson is in charge of security: submit release forms and obtain hard hats and safety glasses.

36.3 (0.2) Turn right (south) at outcrop at east end of plant. The drive through the Northwest Alloy plant provides an appreciation of the lithologic variation and of faults within the Addy.

36.7 (0.4) South gate of Northwest Alloys, with toilet. Vehicles turn around.

STOP 2-5: ADDY QUARTZITE

This is the type locality for the Addy and is described by Dutro and Gilmour, Stop 15, in Joseph (1989) as follows:

"Addy Quartzite crops out on the ridge to the right, north of the road beyond the Allied Chemical fence. Examine this outcrop for Early Cambrian fossils (*Nevadella* and brachiopods). Use care, as we are examining this outcrop with company permission. NOTE: For persons making the trip by themselves, permission must be obtained from the company before entering the area beyond the fence."

Return to US 395 via Addy.

38.4 (1.7) Junction of southern access road to Addy and US 395, turn left (north) toward Colville.

52.9 (14.5) Junction of US 395 and SR 20 at north end of Colville. Stay straight on US 395/SR20.

55.1 (2.2) Turn right (north) on Williams Lake Road.

61.1 (6.0) Turn right (northeast) on Clugston Creek Road. Stay on paved road to Stop 2-6.

68.5 (7.4) Large road cut.

STOP 2-6: FAULTED CONTACT BETWEEN LEDBETTER SLATE AND METALLINE LIMESTONE

This is Stop 8 of Dutro and Gilmour in Joseph (1989); their description follows:

"The contact is in the main roadcut and quarry on the right side of the road (east), and Ledbetter Slate crops out at the south end of the roadcut. Abundant graphtolites in the Ledbetter; Early or early Middle Ordovician conodonts have been collected from the top of and 100 ft below the top of the Metalline Limestone here."

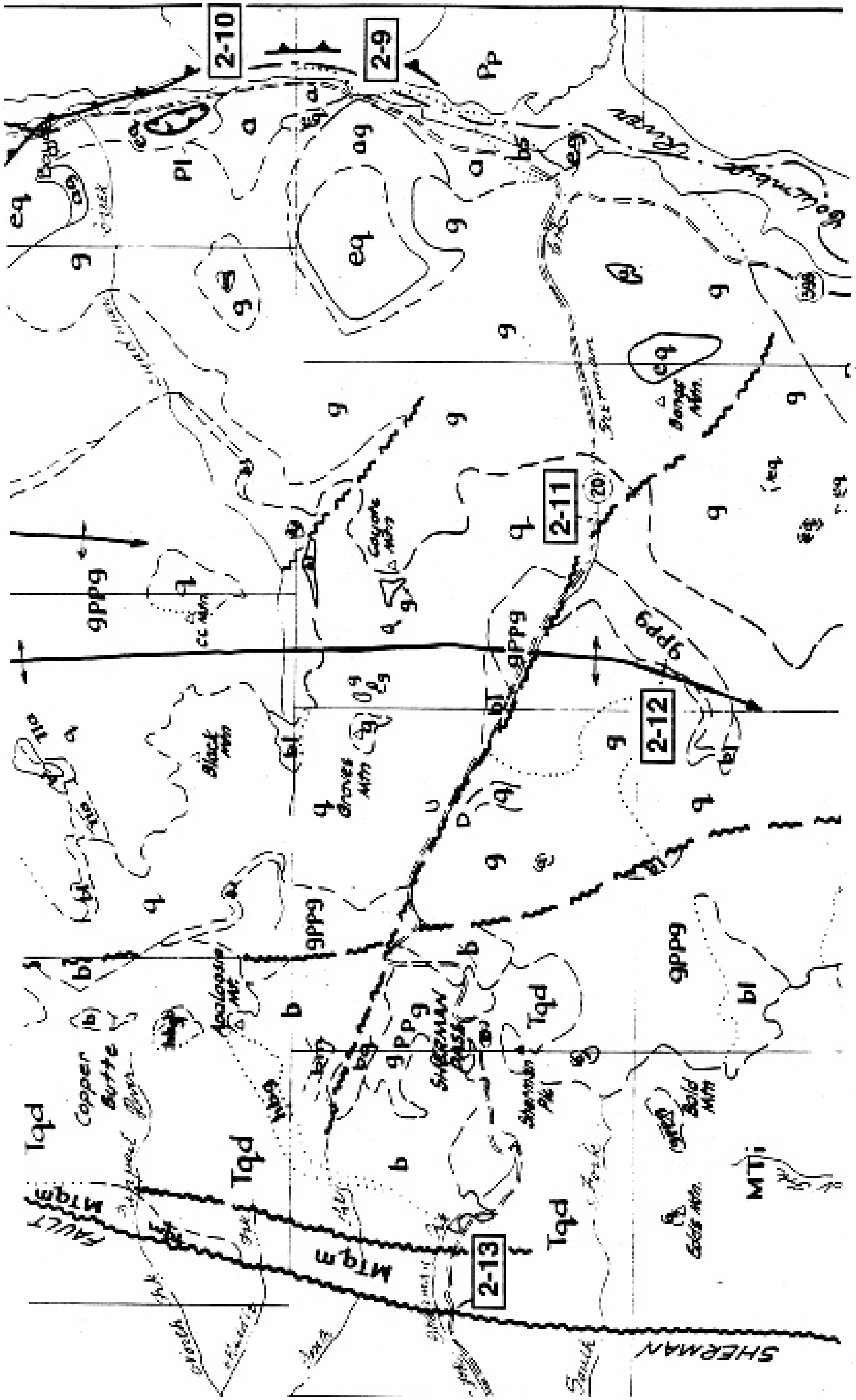


Figure 11. GEOLOGIC MAP OF THE KETTLE METAMORPHIC CORE COMPLEX IN THE VICINITY OF SR 20. Redrafted from Orr and Cheney, Fig. 2, in Schuster.(1987). Note that in this figure the detachment faults are shown by the sawtooth symbol usually used for thrust faults. Fig. 12 is the explanation for this figure. Stops are numbered.

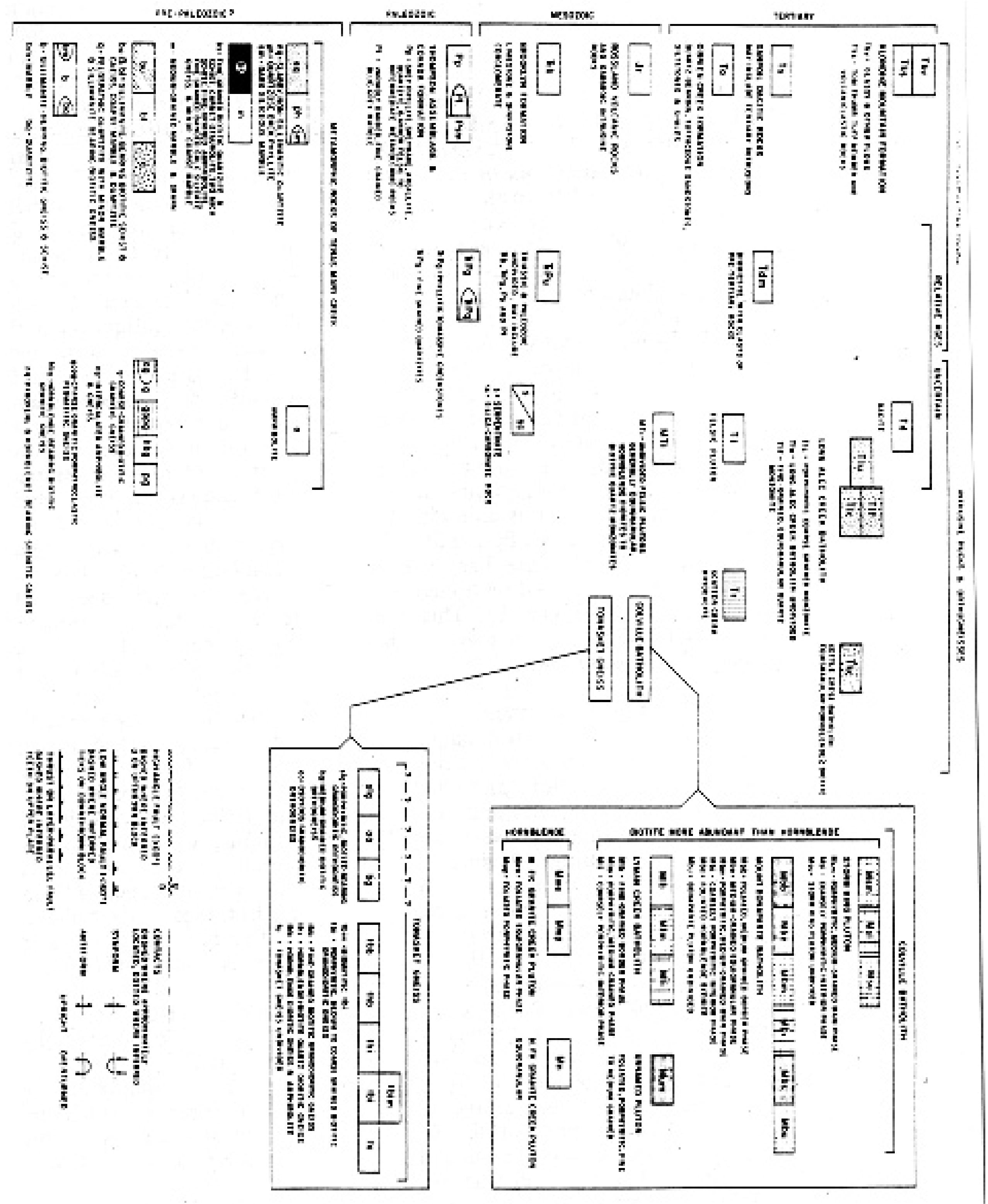


Figure 12. EXPLANATION FOR FIGURES 11 AND 13. Copied from Orr and Cheney, 1987, Fig. 2.

The well foliated and fractured nature of the Metalline is especially obvious in some of the larger blocks near road level. See Fig. 4 for the relative ages of the forma¬tions. Note the unconformably overlying till at the northeast end of the roadcut.

Turn around and return south toward US 395/SR 20.

70.6 (2.1) Quarry and pull-out on right.

STOP 2-7: DEFORMED LEDBETTER SLATE

This also is Stop 7 of Dutro and Gilmour in Joseph 1989.

The Ledbetter is deformed by gently dipping, northwesterly verging folds. The Huckleberry Ridge-Columbia fault system is about a kilometer to the west; so, these folds represent back thrusting of North American rocks over the eastern assemblage and Quesnellia. Return to US 395/SR 20.

82.1 (11.5) At junction with US 395/SR 20 with Williams Lake Road, turn right (west).

84.6 (2.5) Pull into quarry on right (north) side of highway on the west side of the ridge.

STOP 2-8: EASTERN ASSEMBLAGE

The identity of these rocks is enigmatic (Stoffel and others, 1991), but lithologi-cally they seem to most resemble the Bradeen Hill succession (Joseph, 1990). Note that the foliation dips gently to the southeast. The following description is from Stop 9 of Dutro and Gilmour in Joseph (1989):

“Devonian ?/Carboniferous? chert-pebble conglomerate and graywacke on Rattlesnake Mountain. These clastic rocks are thrust eastward against the Metalline/Ledbetter of the Clugston Creek belt; the fault trends north¬ward, contrast these lithologies with the Lower Paleozoic sequence seen [at Stops 6 and 7].”

Continue west on US 395/SR 20.

88.9 (4.3) Main intersection in Kettle Falls.

89.9 (1.0) Junction with SR 25, stay straight (west) on US 395/SR 20.

92.4 (2.5) Bridge over Columbia River (Franklin D. Roosevelt Lake behind Grand Coulee Dam).

92.7 (0.3) Barney’s Junction, turn right (north) on US 395 towards Laurier and Grand Forks and park in front of the motel; then walk 0.1 mile north to the roadcut on US 395.

STOP 2-9: MYLONITIC EASTERN MARGIN OF THE KETTLE METAMORPHIC CORE COMPLEX

The metamorphic rocks of the Kettle MCC are collectively known as the rocks of Tenas Mary Creek (TMC). The metamorphic “stratigraphy” of the paragneisses and sheets of orthogneiss extends northward into British Columbia; the type locality, Tenas Mary Creek, is in the northeastern arm of the Okanogan MCC. Because this stop is on the margin of the antiformal Kettle MCC (adjacent to the Kettle River detachment fault), it is structurally high in the TMC. The most abundant lithology along the west side of the highway is the eastern granodioritic orthogneiss of the TMC. We will compare this unit with the other major orthogneiss (GPPG) at Stop 2-12. Although the cut here has several lithologies, they are lumped with the eastern orthogneiss (g) in Figure 11. This stop is well described by Fox and Wilson as their Stop 7 in Joseph (1989):

“West of the road, amphibolitic gneiss overlies mylonitic augen gneiss, which in turn overlies thinly interlayered amphibolitic gneiss and mylonitic granitic gneiss and pegmatite. Layering and foliation are concordant, dipping 17 degrees east. All rocks are penetratively lineated, the lineation lying in the plane of foliation and trending approximately N75°E. In the granitic gneiss, mylonite grades to or is thinly interlayered with ultra-mylonite. The mylonite is typically light-gray and medium to fine grained and has conspicuous foliation and lineation and abundant larger grains (porphyroclasts) of light gray feldspar, which are milled to spindle shapes. The ultramylonite is darker and much finer grained than the mylonite and has scattered sand-sized light-gray feldspars and poorly developed lineation.

The railroad cut east of the road exposes the upper amphibolitic gneiss. This amphibolite is mottled by lenses of coarse-grained amphi-bole (and garnet), evidently recrystallized following cataclasis. Recumbent isoclinal (intrafolial) folds are abundant. Trends of fold axes in this area show considerable scatter..., but many trend approximately parallel to the lineation. At the north end of the cut, axes of sheath folds and refolded intrafolial folds trend obliquely to the lineation. Small boudins, some of amphibolite within mylonitic granitic gneiss, others of amphibolite, are exposed in cross-section. A small white boudin above the prominent fold in the central part of the cut trends approximately N76°E.

The mylonitic character of the rocks in this area was recognized by Campbell (1938). His carefully worded descriptions are well worth reading. Campbell considered these rocks to be part of the crushed border zone of the Colville batholith. He concluded (1938, p. 94) that the “...brecciated appearance of the rock, the slicing and displacement of the feldspars, the warping of quartz and feldspars as shown by strain shadows, and the lens-like grouping of fine particles about rounded and strained relic crystal...” were evidence of the pressure that had acted on the batholith.

Return to the vehicles and continue northward on US 395.”

93.2 (0.5) Kifer Road on west. Excellent exposures of the eastern quartzite occur in quarries up this road. The quartzite is widely used as decorative stone (note the restau¬rant at Barney's Junction) and as paving blocks ($350/ton in Seattle).

93.7 (0.5) For the next mile, roadcuts are in the amphibolite structurally above the eastern orthogneiss and below the eastern quartzite.

94.9 (1.2) Nancy Creek Road on left (west).

95.6 (0.7) Stop. If necessary, vehicles can proceed 0.4 miles north to the Kamloops Island road to turn around.

STOP 2-10: FOLDED, MYLONITIC EASTERN QUARTZITE

Starting in amphibolite, walk 0.2 miles N050 to the knob west of the railroad track. The eastern quartzite (eq on Figure 11) has cm-scale banding and unusually well developed northwesterly plunging folds. The quartzite is aphanitic (almost porcelainous) and banded (slabby), which is typical of mylonitic quartzites. Gently dipping planes of foliation have a lineation that is NO75° ± 10°. Some of the smaller folds are truncated parallel to their axial planes (causing 1/2 folds). Close inspection reveals that much of the quartzite is intricately fractured, probably because it is within a kilo¬meter of the upper surface of the Kettle River fault.

Return to Barney's Junction.

98.6 (3.0) Barney's Junction, turn right (south) on SR 20 toward Republic and Tonasket.

102.1 (3.5) Excellent outcrop of mylonitic eastern orthogneiss on right.

102.9 (0.8) Junction with road to Inchelium, keep right (straight and westward) on SR 20.

105.7 (2.8) Road to Canyon Creek campground left (south).

106.5 (0.8) Parking here is terrible but the road is straight. If necessary, the vehicles will return to pick us up in 20 minutes.

STOP 2-11: MYLONITIC FELDSPATHIC QUARTZITE

Although on fresh surfaces this quartzite appears to be aphanitic (and porcelainous), it has several percent feldspar porphyroblasts 2-10 mm long (which are best seen on weathered sur¬faces). Contrast the grain size and com¬position with quartzites of previous stops. Note that the rock is lineated. This is the major (< 650 m thick) quartzite of the TMC rocks (q of Figure 11) and best defines the • antiformal nature of the Kettle MCC south of BC; here the rocks dip gently eastward.

108.5 (2.0) South Sherman Road (#2020) turn left (south).

110.5 (2.1) Outcrop on left (north), vehicles can proceed 0.5 miles uproad to turn around.

STOP 2-12: LOWER TMC ORTHOGNEISS

This gray, porphyritic, pegmatitic gneiss is shown as GPPG on Figure 11. Note the 1.5 to 6 cm K-feldspar megacrysts and irregular pegmatitic patches. Note also the lack of ultramylonites and strong band¬ing but some feldspars do have a weak easterly lineation. The gently dipping foliation is due to being near the antiformal axis of the MCC.

Return to SR 20.

112.7 (2.1) Junction of South Sherman Road (Road #2020) and SR 20.

Turn left (west) on SR 20 toward Republic.

124.4 (11.7) Excellent outcrop of GPPG in former streambed, but parking is terrible.

126.4 (2.2) South Sherman Road (#2020).

127.3 (0.9) Very large, biotite-poor pegmatite on right (north) side.

127.7 (0.4) Boudinaged pegmatites with broken feldspars occur in sillimanite-bearing biotitic schists. These biotitic rocks are believed to be structurally below GPPG. Although the pegmatites are some of the most biotitic and radioactive in the Kettle MCC, the quartz is not dark gray to black (which normally is caused by radiation damage).

130.2 (2.5) Sherman Pass.

Sherman Pass (altitude 5575 feet) is the highest pass in Washington that is open to vehicular traffic in the winter. On the south side of the road is the weakly foliated quartz dioritic border phase (with xenoliths and screens of metamorphic rocks) of the Tertiary Kettle Crest batholith intrusive into the TMC metamorphic rocks.

The easternmost outcrops on the north¬ern side of the pass are GPPG. Westward on the bench above the highway is the contact of GPPG withwesterly dipping sillimanite-bearing gneiss and amphibolite. The relative structural positions of the GPPG and the sillimanitic pelitic rocks cannot be determined here, but the map pattern to the north indicates that GPPG may be the structurally higher unit. The steep dips here are characteristic of the western margin of the Kettle MCC.

A 1/2 mile walk northward along the Kettle Crest trail starts in the quartz diorite and passes into sillimanitic pelitic rocks with weakly radioactive, boudinaged pegmatites. At the power lines is a good view westward across the Republic structural low; the jagged peaks in the farthest distance are in the Pasayten Wilderness.

133.6 (3.4) USFS "Point of Interest" about the 1988 White Mountain forest fire.

135.6 (2.0) Colville National Forest boundary.

136.6 (1.1) Park on right (north side of road).

STOP 2-13: SHERMAN FAULT

At this locality the Sherman fault is the eastern bounding fault of the Republic graben. The graben is predominantly a synformal inlier of Challis rocks between the antiformal Kettle and Okanogan MCC.The fault separates Challis and Quesnellian rocks on the west from Challis-aged granitic rocks of the western limb of the Kettle MCC. The fault is unusual here in that it is marked by serpentinite (which, presumably, is related to the adjacent Quesnellian greenstones).

137.1 (0.4) Outcrops for the next half mile are massive, white, volcani-clastic sandstones and interbedded dark siltstones and shales of the O'Brien Creek Formation. The O'Brien Creek is the basal unconformity-bounded sequence of the Challis sequence (Fig. 9). The brownish and knobby weathering rocks for the next 9 miles to the junction of SR 20 and SR 21 are the Sanpoil Volcanics; these felsic rocks are the next sequence above the O'Brien Creek.

144.8 (7.7) Junction of SR 20 with SR 21 to the north to Curlew and Grand Forks, stay straight ahead (west) on SR 20.
147.5 (2.7) Junction of SR 20 with SR 21 to the south to Keller and Wilbur; turn right (north) toward Republic.

147.8 (0.3) Republic. Park in front of Michael's Restaurant. Walk back 0.1 miles to see unaltered fine¬grained tuff (with leaf and insect fossils) on the southern edge of Republic. This is the basal Tom Thumb Tuff of the Klondike Mountain Formation. A joint meeting with the Northeast Washington Geological Society (NEWGS) will be at Michael's.

END OF DAY TWO

LOCAL DIRECTIONS FROM REPUBLIC

TO BLACK'S BEACH RESORT AND ECHO BAY LAKE HOUSE

0.0 (0.0) Blinker in downtown Republic, proceed north (uphill).

0.15 (0.15) At T junction in front of the stone Episcopalian Church turn right.

7.5 (7.3) Turn right for Black's Beach Resort.

8.0 (0.5) Road to right. If going to Echo Bay Company's lake house, follow this curving road to its end (0.5 miles). Stay left for Black's Beach Resort.

8.2 (0.2) Entrance to Black's Beach Resort.

TO CURLEW STATE PARK

Follow the directions for Day Three from miles 0.0 to 3.9. Instead of turning right at 3.9, continue north on SR 21 to the Lamefoot mine. Turn left 0.2 miles past Lamefoot into Curlew State Park.

TO CAMPING AT THE FERRY COUNTY FAIRGROUNDS

Follow the directions for Day Three from 0.0 to about 2.8 miles; turn right into the fairgrounds (before the junction of SR 20 and SR 21 north to Curlew, mile 3.1 on the road log). Follow the road around to the right.

TO SWEAT CREEK CAMPGROUND

Follow the directions for Day Three from 38.5 to 46.8 miles.

DAY THREE: REPUBLIC TO OROVILLE

0.0 (0.0) Reset odometer at the blinker in downtown Republic and proceed south (downhill) on SR 20.

0.6 (0.6) Turn left at junction of SR 20 and 21.

3.1 (2.5) Turn left on SR 21 toward Curlew and Grand Forks.

3.9 (0.8) Turn right on Old Kettle Falls Road.
The knob on the north side of this corner is Gold Hill, which had very limited past production despite its name. It is underlain by Quesnellian rocks (and Tertiary Scatter Creek dikes); so at this latitude, only the western half of the Republic graben is extensively underlain by Challis rocks.

6.3 (2.4) Turn left toward Echo Bay Minerals Co.

7.7 (1.4) Security gate for Echo Bay Minerals Company's Kettle River Operations. Stop for clearance.

10.3 (2.6) Stay right (east) at fork in road.

12.5 (2.2) Shop and office trailer for Key East and Key West mines. We will drive to various parts of these mines. The major stop will be Key West.

STOP 3-1: KEY WEST OPEN PIT MINE

The ores of the Lamefoot, Overlook, Key East, and Key West are in the Attwood Group of the Quesnellian rocks (Fig. 12A). In addition to seeing the ore, this is a rare opportunity to examine the felsic volcaniclastic rocks associated with the ore.

These rocks normally do not crop out well and, in any event, are under-reported in the Attwood Group.

Two ore types were mined at Key West: (1) massive magnetite-pyrrhotite-chalcopyrite and (2) veinlets of quartz-pyrite-chalcopyrite above the massive ore. Note that a dike of Scatter Creek in the upper benches of the pit is associated with a zone of deformation that disrupts the massive ore.

Return to the Company's security gate.

20.7 (8.2) Take the first right (less than 0.5 miles) past the security gate.

22.4 (1.7) Turn right (north) on SR 21.

25.3 (2.9) Lamefoot mine is on right (east).

25.4 (0.1) Turn right on Wolf Camp Road. The retaining walls of concrete blocks 0.2 to 0.6 miles up the road were used in 1990 to 1991 to collar drill holes used to develop LamefooL

27.2 (1.8) Stop.

STOP 3-2: LAMBERT CREEK DETACHMENT FAULT

This fault was originally mapped as a thrust by Muessig (1967). It is now believed to be a top-to-the-east detachment fault on the west side of the Kettle MCC (Fig. 12A). It is cut by the high angle Sherman fault, which bounds the Republic graben on the east at this latitude.

The extensive limonite is from weathering of sulfides (predominantly pyrite). For future reference (Stop 4-6), imagine what this rock would look like if all of the limonitic fractures were chloride instead.

Note that clasts in the breccia consist of laminated siliceous rocks and chert/bull quartz of the Attwood Formation and volcanic rocks of the Sanpoil Volcanics. A porphyritic rock, locally veined but rarely brecciated, cuts the breccia.

Return to SR 21.

29.0 (1.8) At SR 21, turn left (south) toward Republic.

32.8 (3.8) Turn right (west) on Herron Creek Road.

33.8 (1.0) Turn left toward Republic.

38.3 (4.5) Turn left at Episcopal Church onto Clark Avenue in Republic.

38.5 (0.15) At the blinker in central Republic, turn right to the west. In the city park 150 feet to the west note the large golden cube commemorating the cumulative production of 2,000,000 ounces of gold from the Knob Hill mine in 1989.

38.6 (0.3)

STOP 3-3: KLONDIKE MOUNTAIN FORMATION, O'BRIEN CREEK FORMATION, AND SCATTER CREEK RHYODACITE

Walk westward along SR 20 for about half a mile to the other side of the valley. Vehicles will pick us up on the far side. Coarse pyroclastic rocks of the basal part of the Tom Thumb tuff member of the Klondike Mountain Formation crop out east of the creek. Hecla geologists now include the Tom Thumb in the Sanpoil Formation (Tschauder in Joseph, 1989). The arigilitic alteration of the Klondike Mountain and O'Brien Creek formations is due to weathering of the disseminated pyrite.

At the west end of the traverse, the O'Brien Creek Formation, with characteristic black phyllite chips, is intruded by dikes of Scatter Creek rhyodacite. Pervasive diagenetic laumantite makes the volcaniclastic rocks of the O'Brien Creek (and correlative rocks) characteristically white. The dikes have feldspar and hornblende phenocrysts (greater than 1 cm), which are characteristic of the Scatter Creek. Both the O'Brien Creek and the Scatter Creek are faulted, pyritic, and somewhat altered. (Note the evidence of a former mine.)

The juxtaposition of the Klondike Mountain Formation against the O'Brien Creek Formation without any (or much) interbedded Sanpoil Volcanics implies that the creek is the trace of a fault. This fault was named the Republic fault by Muessig (1967), who described additional evidence for it. 40.8 (2.2) The Swamp Creek Valley to the north marks the trace of the Bacon Creek fault, the eastern bounding fault of the Okanogan MCC (Fig. 13). The outcrops for the next 5 miles are in hornblende-bearing granitic rocks, which are minor rock types within the slightly foliated, biotitic, quartz dioritic to quartz monzonitic plutons of the "Colville batholith."

46.8 (6.0) Sweat Creek Campground: Possible rest stop. On the hill northeast of the campground are columnarly jointed, glassy, black flow rocks typical of the upper portion of the Klondike Mountain Formation (minimum age 41 Ma).

Return to SR 20.

47.2 (0.4) Junction with SR 20, turn right (west) toward Tonasket.

47.7 (0.5) On the south side of SR 20 is an unsorted, unstratified rock (diamictite), the clasts are predomi¬nantly hornblende-bearing granitic rock, but westward the number of non-granitic clasts, especially am-phibolite, increase. One block of amphibolite is about 2 m long. On the north side of the valley 0.6 miles to the west, the diamictite contains a sandy lens 7 m long and 0.3 m thick with 5 to 8 cm layering. Here, the diamictite is overlain by the glassy flow rocks of

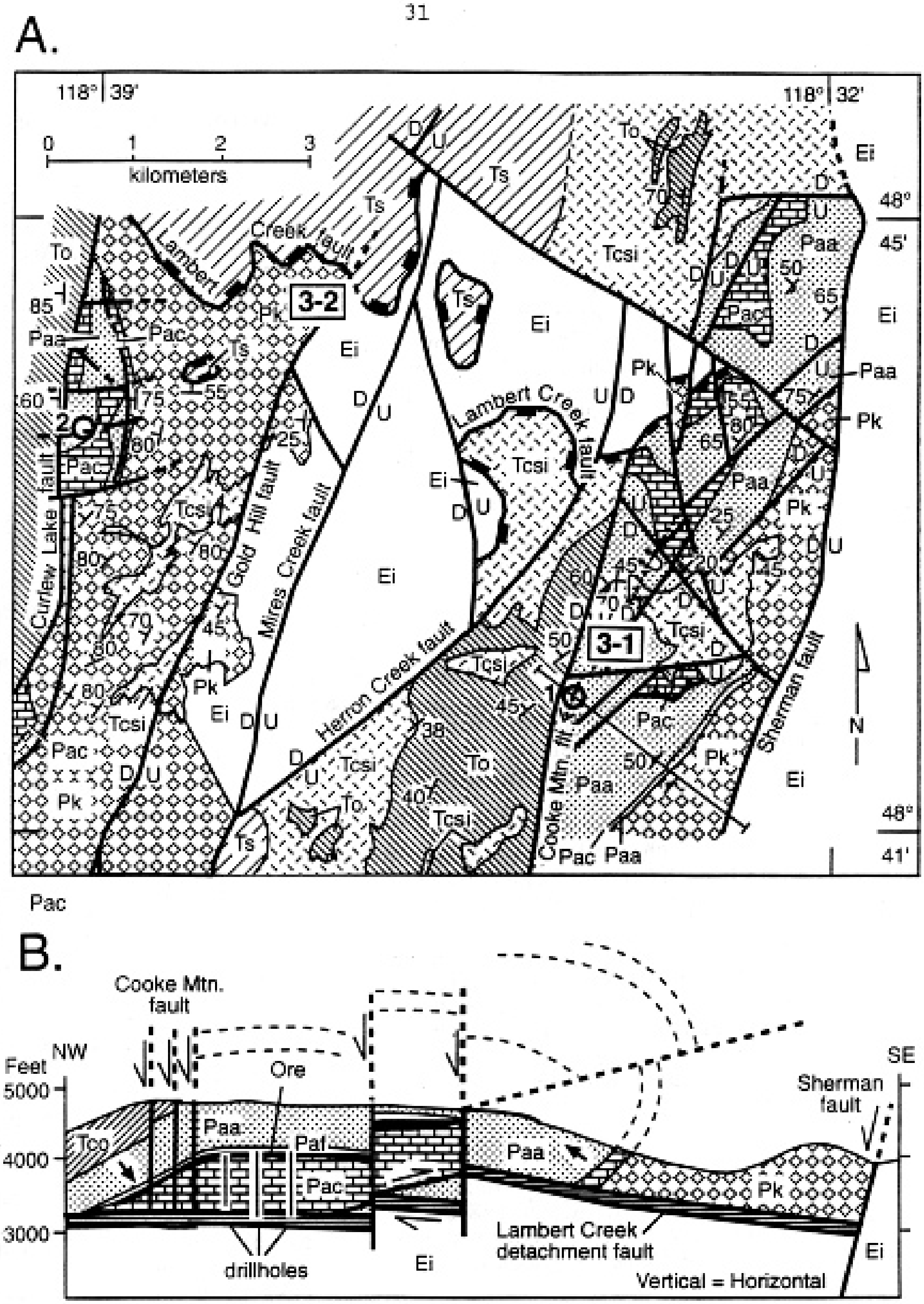


Figure 12A. GEOLOGIC MAP OF THE LAMEFOOT OVERLOOK-KEY AREA
Modified from Cheney and others (1993), Fig. 5 in Lasmanis and Cheney (1993). In A, mineral deposits are 1, Overlook; 2, Lamefoot; and 3-1, Key. Note that the geologic cross section of the Overlook mine in B is a different scale then A. Bold inclined arrows in B illustrate the facing direction of graded beds.

the Klondike Mountain Formation. Similar angular conglomerates were mapped by Fox (1970) and described by Pearson and Obradovich (1977) below the arkosic and volcaniclastic rocks of the sequence represented by the O'Brien Creek Formation.

48.4 (0.7) Medium-grained hornblende-bearing granitic rock is cut by numerous breccia dikelets and hair-line fractures. At the west end of the southern side of the road cut, an unbrecciated porphyritic dike similar to the rocks at Mile 49.4 cuts the brecciated granitic rocks.

Similarly, but less intensely, brecciated granitic rocks occur as much as 1.1 miles east and 3 miles northwest (south of the low-grade metamorphic rocks of Wauconda summit). The metamorphic discontinuity of Stop 3-4 and at Mile 49.7, plus these brecciated granitic rocks, probably define the trace of a low-angle (detachment) fault.

49.4 (1.0) A small porphyritic intrusion (or lava dome) of unknown age with spectacular flow banding is in a quarry on the left (south). Non-flow banded portions with columnar jointing parallel the flow banding. Approximately 100 m to the east on the northern side of the road, porphyritic rocks intrude brecciated rocks like those a mile to the east.

49.7 (0.3) The road traverses amphibolite facies rock of the Okanogan MCC for the next mile.

52.1 (2.4) Wauconda Pass. The road traverses greenstones for the next 1/2 mile and then passes through gray phyllites. These rocks are outside of (or above) the MCC (Fig. 13).

52.3 (0.3)

STOP 3-4: MYERS CREEK DETACHMENT FAULT

Examine the presumed Attwood phyllite and fine-grained quartzite near the driveway and then walk westward down SR 20. Do not cross the fence.

North of the fence approximately 100 m west of the quartzite, is fine-grained limestone typical of Attwood rocks. About 130 m west of the limestone, amphibolite occurs at the fence line; another 20 m to the west are outcrops of garnet-staurolite, two-mica schist. Speculate on the nature and orientation of the contact between the rocks of different metamorphic grades. Continue westward on State Route 20.

55.6 (3.3) Wauconda P. O., store, and restaurant. For the next three miles the high mountain to the north is Mount Bonapart (7257 feet). It is part of the Challis-aged Mount Bonapart pluton, a tabular, easterly dipping batholith on the eastern margin of the Okanogan MCC.

62.1 (6.5) The road curves through a narrow gully. The rocks are the migmatitic basal zone of the Mount Bonaparte batholith. Rocks west of here are westerly dipping Tonasket gneiss.

66.7 (4.6) Aeneas Valley road is on the left (south). From here to Tonasket, the Tonasket gneiss has a regional westerly dip. Reversals in the dip of the foliation, such as the obvious one 3 miles to the west, mark post-mylonitic northwesterly striking folds.

79.9 (13.2) Upon entering Tonasket, turn left on Tonasket Avenue (one block east of the junction of SR 20 with US 97). Proceed one block to Seventh Street and turn left (east) and follow it to the end of Mill Drive.

80.4 (0.5) At the end of Mill Drive, walk 0.1 mile eastward to the stream (see Figure 7 for the geology of the Okanogan Valley).

STOP 3-5: ULTRAMYLONITIC TONASKET GNEISS
Note the "cherty interlayers" (ultra-mylonites) within the Tonasket gneiss and that they and the gneiss are cut by chloritic fractures. This is the mylonitic part of the Okanogan detachment fault on the west side of the MCC.

Return to US 97 via 7th Street.

80.9 (0.5) US 97 turn right (north) to Oroville. Note Whitestone Mountain west of the highway north of town. The white stone of the lower 3/4 of the mountain is identical to the O'Brien Creek formation of the Republic area. The brown upper part is identical to the Sanpoil Volcanics.

98.7 (17.8) In Oroville at the Chevron station turn left (west) on Central Avenue (marked by signs for Nighthawk and Golf Course).

101.1 (2.4) Entrance to Oroville Golf Course. Vehicles will turn around 1/4 mile to the northwest and wait for us.

STOP 3-6: QUESNELLIAN LITHOLOGIES AND STRUCTURE

See Figure 7 for the regional geology. Using Figure 14 walk 0.6 miles along and above the road to observe various Quesnellian lithologies (especially listwan-ites) and structures.

Return to Oroville.

103.7 (2.6) Intersection of Nighthawk road (Central Avenue) and US 97, turn right (south).

104.0 (0.3) Turn right (west) to Lake Wannacut.

104.3 (0.3) Bridge over Similkameen River.

105.0 (0.7) Turn right at Golden Road to Wannacut Lake.

105.1 (0.1) Stay left at fork in road.

106.8 (1.7) Turn right on Blue Lake

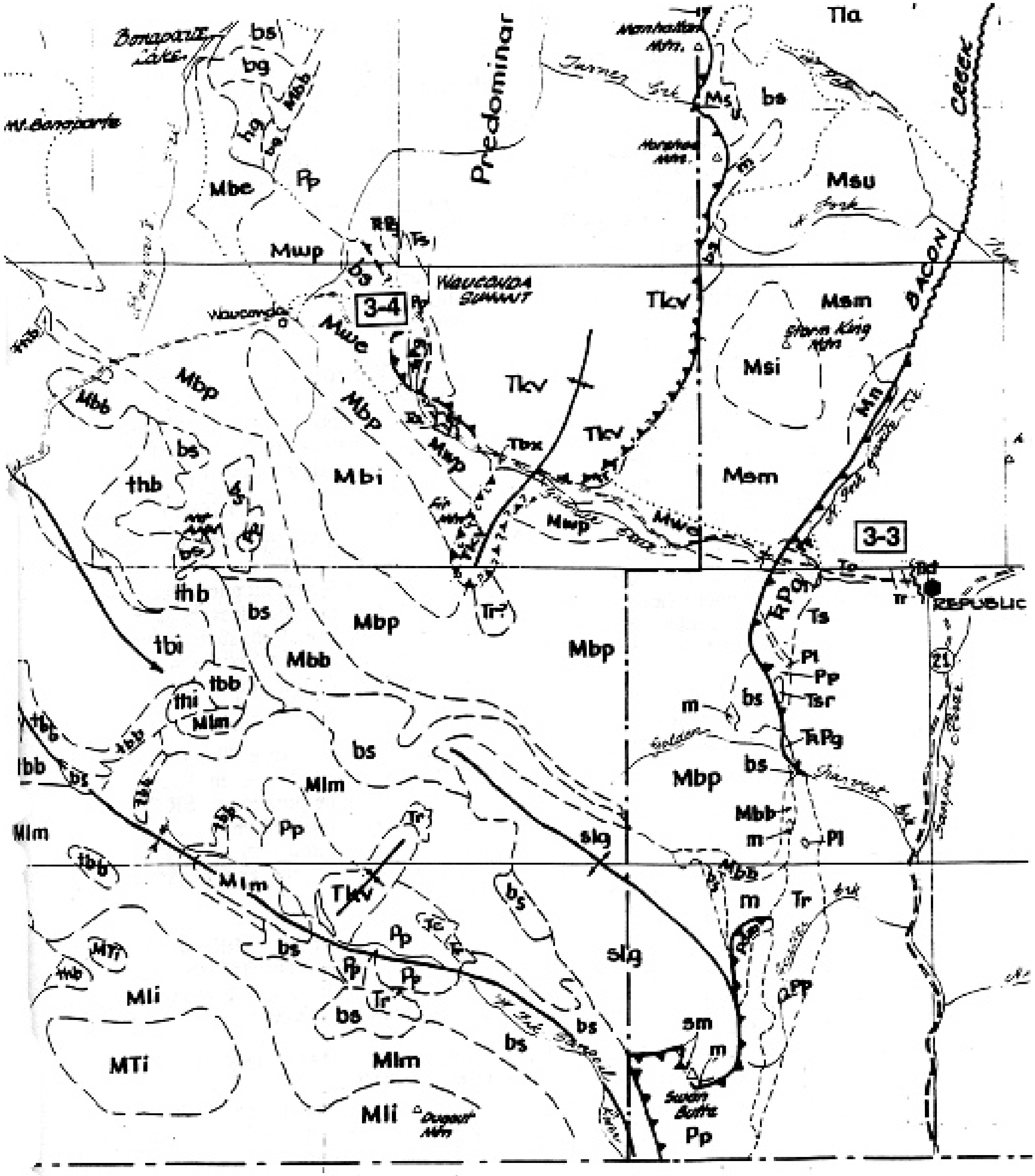


Figure 13. GEOLOGIC MAP OF THE OKANOGAN METAMORPHIC CORE COMPLEX IN THE VICINITY OF SR 20. Redrafted from Orr and Cheney, Fig. 2, in Schuster (1987). Note thaj in this figure detachment faults are shown by the sawtoothed symbol usually used for thrust faults. Figure 12 is the explanation for this figure. Stops are numbered.

Road to Wannacut Lake.

109.4 (2.6) Road to Blue Lake boat launch.

110.2 (0.8) Isthmus on northeast end of Wannacut Lake on left (south). The vehicles can proceed 0.9 miles west to turn around at a road junction and will return for us.

STOP 3-7A: CHESAW THRUST

See Figure 7 for the regional geology. Make a 1.0 mile (round trip) traverse along the northeast end of Wannacut Lake to see the lithologies of Figure 15. Perhaps the most instructive aspect of this traverse is to see that metadiorite in the footwall of the thrust becomes green phyllitic slate (mmp of Figure 15).

Return to the vehicles and start return trip to Oroville.

110.7 (0.5) Wide area in road opposite outcrop on north (left).

STOP 3-7B: SHEARED ELLEMEHAM FORMATION (ROSSLAND GROUP)

This is the hangingwall of the Chesaw fault. Walk eastward to the road to the Blue Lake boat launch. Excellent examples of coarse volcaniclastic Ellemeham Formation occur at the southwest shore of Blue Lake.

Return to Oroville. 116.7 (6.0) Downtown Oroville.

END OF DAY THREE

DAY FOUR: OROVILLE TO EAST WENATCHEE

0.0 (0.0) In downtown Oroville at the intersection of US 97 and Central Avenue, proceed south on US 97.

17.6 (17.6) Tonasket.

19.6 (2.0) Tonasket gneiss with "cherty" ultramylonite and chloride fractures.

21.9 (2.3) Bridge over the Okanogan River.

US 97 crosses the Okanogan River and follows Wagon Road Coulee (along the trace of the Okanogan detachment fault). However, the Okanogan River forsakes the fault and swings southeastward into the Okanogan MCC. The river emerges from the MCC at Riverside (Stop 4-2). The Similkameen River has a similar diversion: instead of following the broad valley through Palmer Lake, Loomis, and Spectacle Lake, it cuts the gorge northwest of Oroville at Stop 3-5. As we proceed southward down Wagon Road Coulee to Stop 4-2, note, especially, the large kettles. South of 4-2 are large outwash terraces. The stockpile of white rock east of US 97 is high-calcium marble from north of Wauconda in the Okanogan MCC. Anarchist (western assemblage) marbles have too much MgO to be very valuable.

26.4 (4.5) Deep kettle on right (west) is the site of Crumbacher Lake.

29.7 (3.3) Power line crosses US 97.

30.7 (1.1) Pull out on west side of US 97.

STOP 4-1: RECUMBENT FOLD IN CAVE MOUNTAIN FORMATION

A recumbent fold occurs in the cliff on the west side of the coulee. US 97 follows the trace of the Okanogan detachment fault, which here must floor the Cave Mountain Formation and the Chesaw Fault. Presumably the recumbent fold in the carbonate rocks of the Cave Mountain Formation predates the Okanogan MCC.

33.8 (3.0) On the south side of Riverside, pull off on right (west) toward Conconully at junction of Johnson road.

STOP 4-2: MYLONITIC HOGBACKS OF OKANOGAN MCC

The mylonic hogbacks of the western limb of the Okanogan MCC are especially well developed where the Okanogan River emerges from the MCC.

Until the coming of the railroad in 1914, Riverside was the head of navigation for steamships up the Okanogan River from the Columbia River. It was a "jumping-off point" for the Cariboo gold rush in 1859 and I860.

Continue west on Johnson Road toward Conconully.

37.1 (3.3) Turn right (west) toward Conconully

39.4 (2.3) Junction with Limebelt Road on right (north).

STOP 4-3: PORPHYRITIC PHASE OF EVANS LAKE PLUTON

This is the Leader Mountain gneiss, one of the most distinctive rocks of the southwestern metamorphic belt (Mom of Fig. 7). Previous mappers have included it as .the porphyritic phase of the Evans Lake pluton, which is shown as pluton E on Figure 7. Note the hornblende and the K-spar megacrysts and compare the foliation here with that at Stop 4-4.

Turn around and head southeast toward Riverside and Omak.

41.3 (1.9) Stop at Haeberle Ranch house on right to submit release forms for Stop 4-4.

41.6 (0.3) Turn left (northeast) on dirt road to Stop 4-4. Sign on gate: NSA Camp. Walk or drive. The traverse is rough

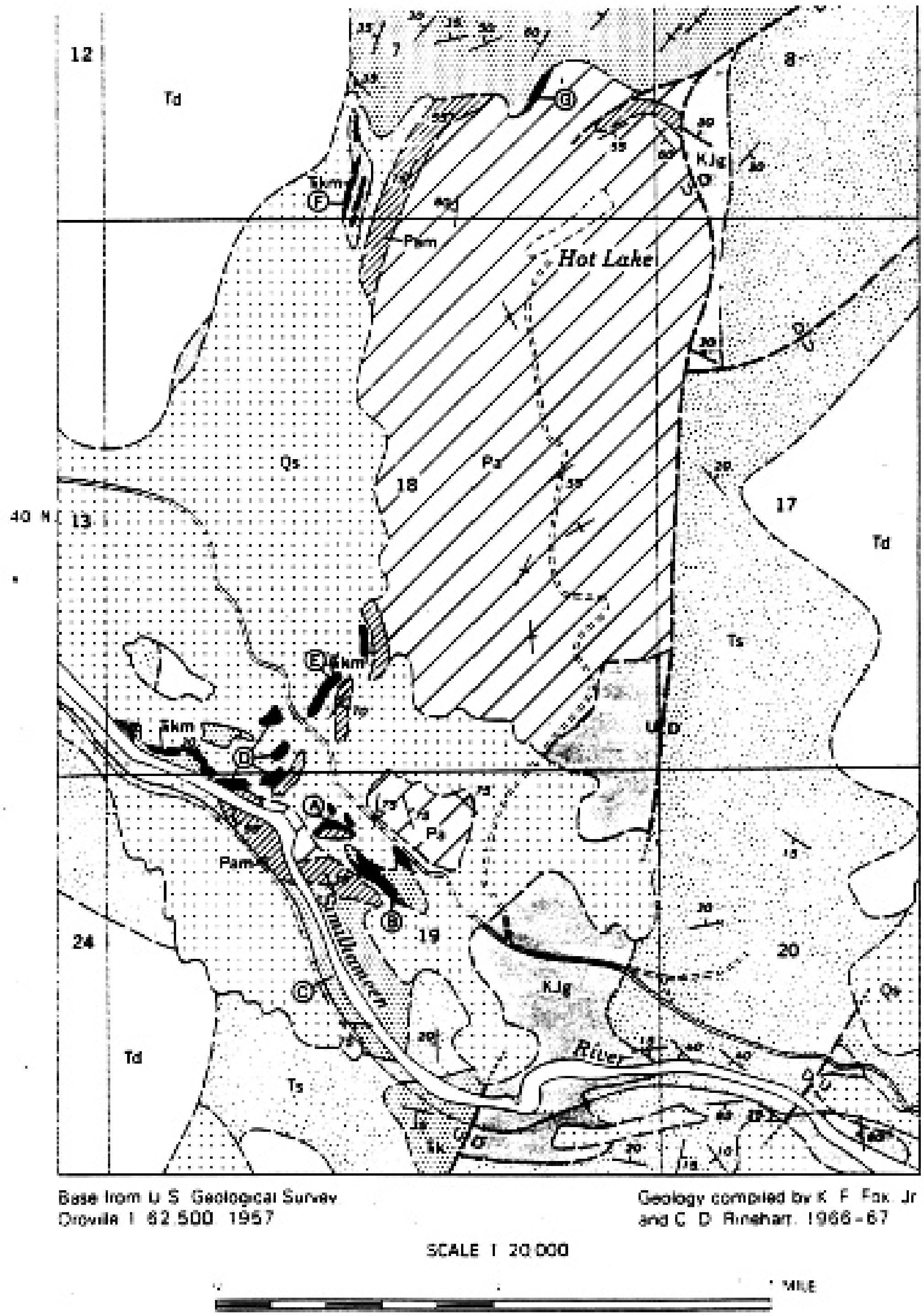


Figure 14. GEOLOGIC MAP OF THE OROV1LLE GOLF COURSE AREA.
Copied from part of Fox and Rinehart, 1968, Plate 1. Neither this map nor Fox's slightly revised version (1970) of it depicts the Chesaw fault. Units are: Qs, undifferentiated Quaternary; Td, Tertiary dacite; Ts, Tertiary sedimentary rocks; KJm, Ellemeham greenstone; Trk, Kobau greenstone; Trm, magnesite; Pa, Anarchist conglomerate, graywacke, and siltstone; Pam, Anarchist, marble.

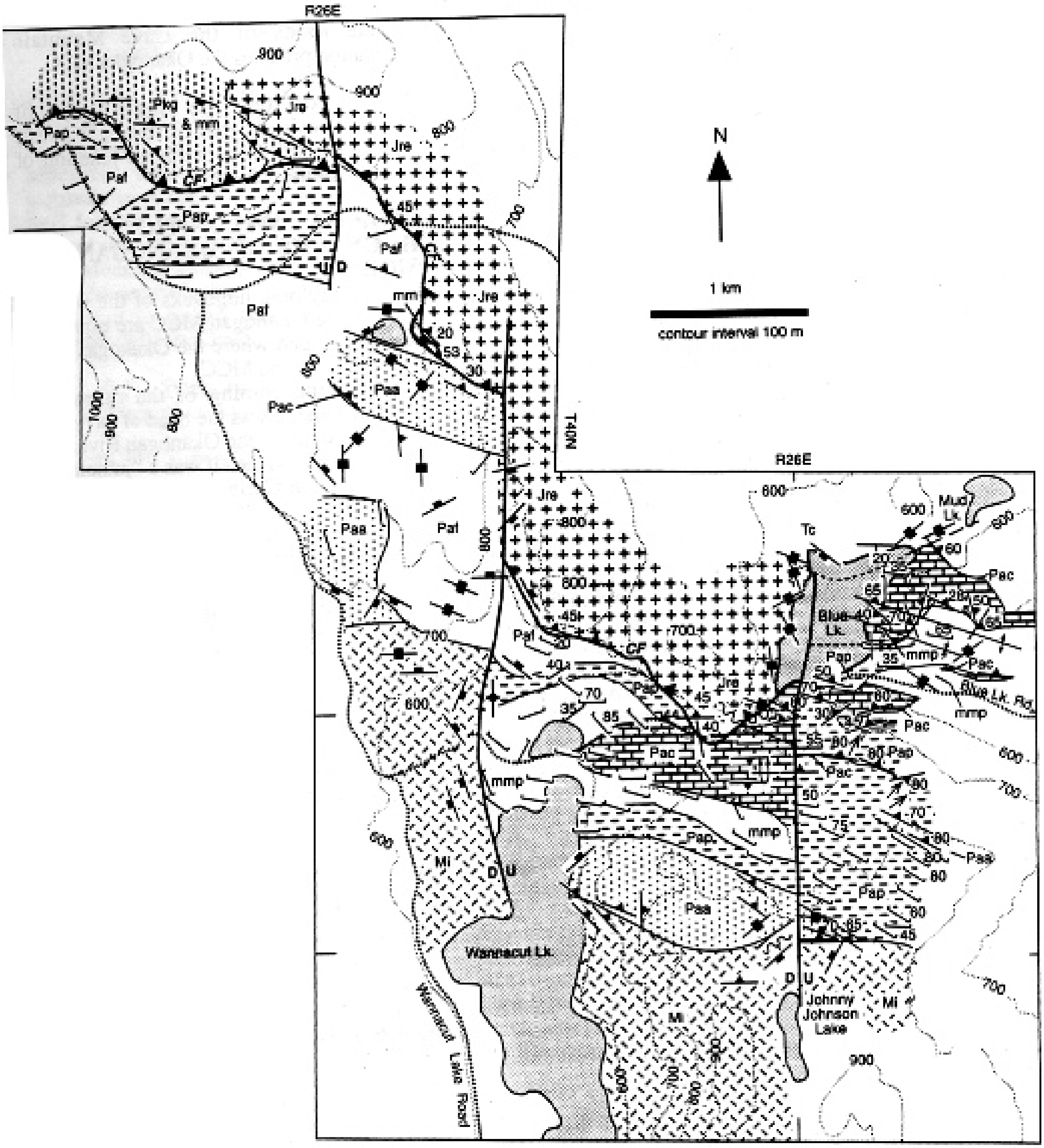


Figure 15. GEOLOGIC MAP OF THE CHESAW FAULT AT WANNACUT LAKE.

Geology by E. S. Cheney, 1992, 1993. Units which do not appear in the Explanation to Figure 3 are: Mm, mafic pluton; Mmp, phyllitic mafic pluton; Pag, greywacke of the Atrwood Formation; and p, pegmatite and aplite.

(but not tough). If driving, do not record mileage.

Beware of rattlesnakes on the traverse.

STOP 4-4: CHESAW AND DUNN MOUNTAIN FAULTS

Figures 7 and 16 show the Cave Mountain limestone in contact with serpentinite (Chesaw fault) and the very well foliated Leader Mountain gneiss in contact with noncontact metamorphosed Cave Mountain limestone and serpentinite (Dunn Mountain fault).

Return to paved road and continue southeast (left) for Omak.

41.8 (0.2) Fork in road, stay right (straight) for Omak.

46.1 (4.3) Turn left for Omak. 47.1 (1.0) Turn right for Omak.

47.8 (0.7) Turn left for Omak.

White outcrops on north side of road are Tertiary volcaniclastic rocks equivalent to the O'Brien Creek Formation.

48.7 (0.9) Turn right for downtown Omak.

49.1 (0.4) At traffic light in downtown Omak (Central Avenue) turn right.

49.3 (0.2) Proceed one block to the municipal park for rest stop.

Return to traffic light.

49.5 (0.2) Traffic light, stay straight on Central Avenue, which is SR 155.

52.4 (2.9) Turn left (north) off SR 155 on dirt road.

52.7 (0.3) Turn left (west) on dirt road toward quarry.

52.9 (0.2) Quarry (Fig. 7)

STOP 4-5: MYLONITE OF THE OKANOGAN DETACHMENT FAULT

The mylonitic carapace of the Okanogan MCC here is 1.0 to 1.5 km thick. We will examine the feldspar megacrystic granifefor the classic mylonitic textures; porphyroclasts (with pull-apart quartz veinlets that do not cut the matrix of the rock), lineations, finer-grained zones and two foliations (S-C fabrics). S-C fabrics indicate that the sense of displacement on the Okanogan detachment fault is top-to-west.

Return to SR 155.

53.4 (0.5) SR 155, turn right (west) toward Omak.

55.2 (1.8) Turn right (north) on Co. Rd. 3735 opposite lumber mill yard.

58.4 (3.2) At second right angle turn stay straight (east) on driveway south of greenhouses.

58.7 (0.3) End of driveway. Walk southwest 200 m along fence line (Fig. 7).

STOP 4-6: BRECCIA OF THE OKANOGAN DETACHMENT FAULT

Chloritic granitic breccia (aka "junk-rock breccia") marks the outer margin of the Okanogan detachment fault. Such rocks rarely crop out in northeastern Washington. The protolith of 4-6 is 4-5, that is, the breccia is a later cataclastic (and presumably shallow) deformation superimposed on the ductilely deformed (mylonitic) rocks.

Turn around and return toward Omak.

62.7 (3.5) At junction with route SR 155 turn right (west) toward Omak.

63.4 (0.7) US 97, turn left (south) toward Wenatchee. Add 1.1 miles to cumulative mileage.

90.7 (27.2) Turn left on SR 17.

96.3 (5.6) Road on right is to Colville Confederated Tribe Trout Hatchery.

96.5 (0.2) Wide pullout on right along a curve in highway

STOP 4-7: NORTHERN MARGIN OF THE COLUMBIA RIVER PLATEAU

Two significant unconformities occur beneath the CRBG. A recessive unit oc¬curs between CRBG and the crystalline basement and forms the broad bench below the CRBG. The quarry in buff rock (deeply weathered granitic basement) is below the bench and the recessive unit. The basal contact of the bench is discordant to the overlying CRBG. This recessive unit is arkosic sandstone in the Foster Creek drainage to the south. Although this unit is generally regarded as Miocene (Stoffel et al., 1991), and presumably thereby related to the CRBG, its arkosic nature and discordance to the CRBG suggest that it is one of the Challis arkosic sequences. However, east of Foster Creek along SR 17, the strata beneath the CRBG are much finer grained and may not be Challis.

The Chief Joseph dam (which comes into view in 1.3 miles) is, of course, anchored in the granitic basement.

Continue southward across the Columbia River.

101.0 (4.5) Turn right to Mansfield. If this road is under construction, make a 27 mile detour to the east via Mansfield.

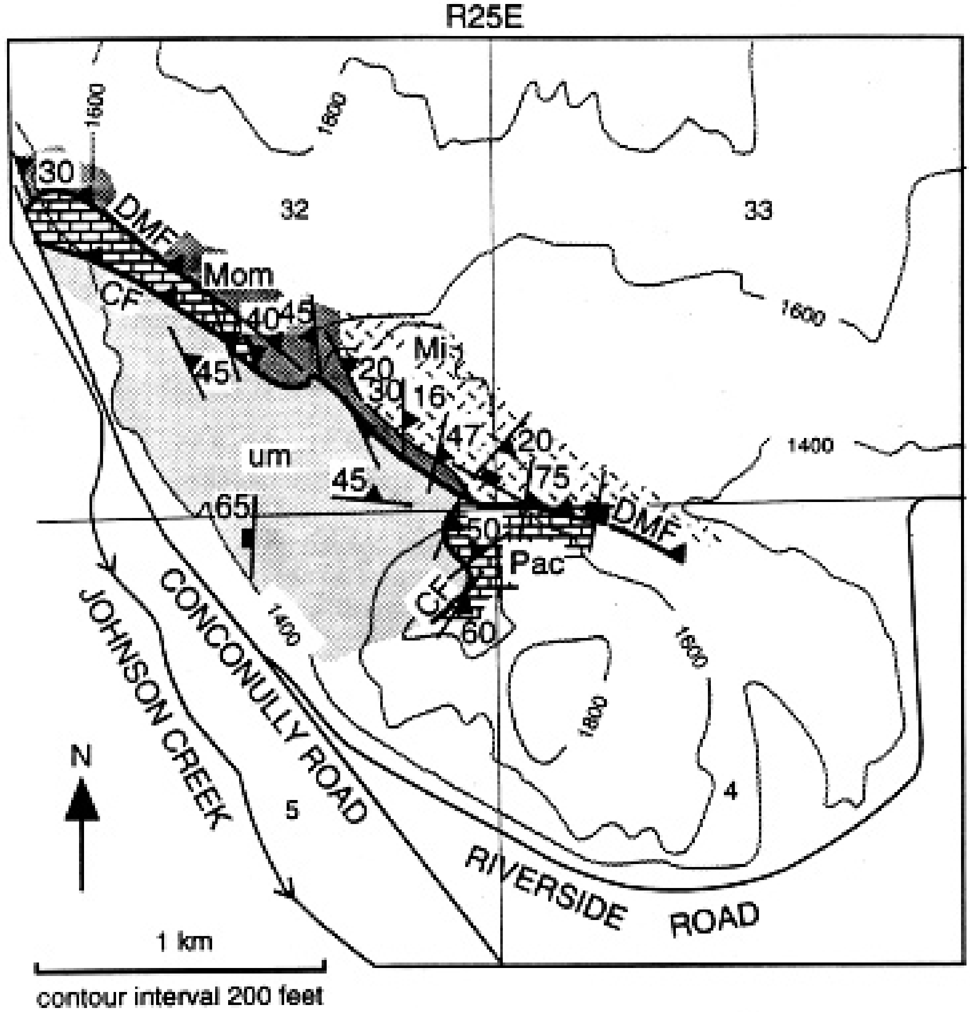


Figure 16. RECONNAISSANCE GEOLOGIC MAP OF THE SOUTHERN SIDE OF THE EVANS LAKE PLUTON. Mapping by E. S. Cheney, 1991, 1993. See Explanation to Figure 3.

From here to US 2 is a Winnebago-free zone. Preserve it.

113.2 (12.2) Junction of B NE with 14 NE (SR 172) turn right (west) on 172 toward Waterville.

The surface of the Waterville Plateau is dotted by black “haystack rocks,” erratics of CRBG deposited by the Okanogan lobe of continental ice.

122.2 (9.0) 10 NE Street.

123.2 (1.0) Just over the crest of the hill is a small pullout on the right at 9 NE Street.

STOP 4-8: WITHROW MORRAINE

To the south below the morraine is Withrow and the relatively flat surface of the Waterville Plateau. The ridge to the southwest is Badger Mountain, an anticline in CRBG between here and Stop 4-9. Behind Badger Mountain in the distance (40 miles) is Mission Ridge south of Wenatchee. Mission Ridge is underlain by CRBG which dips easterly off the Cascade Range. To the west is the Cascade Range dominated by Mount Stuart (9415 feet).

132.2 (9.0) Turn right (west) on US 2 toward Wenatchee.

141.9 (9.7) Douglas.

143.7 (1.8) Foreset (deltaic) pillow-palagonite unit in CRBG.

146.3 (2.6) Downtown Waterville is a right angle turn in US 2 at the intersection of Locust and Chelan; leave US 2 by continuing (south) for Badger Mountain ski area.

148.8 (2.5) Take right fork for E. Wenatchee.

164.8 (16.1) Begin steep descent to East Wenatchee.

165.8 (0.9) Pull off on left adjacent to a grassy knoll.

STOP 4-9: OVERVIEW OF THE WENATCHEE AREA

The panorama is dominated by Mission Ridge, Wenatchee, and the Columbia River to the southwest and by Mount Stuart to the west. To the west, the ridge descending to US 2 has a clump of trees, which is Ohme Gardens State Park. Beyond this ridge is the southwesterly striking Entiat fault that intersects the northern tip of Wenatchee Heights (note variable dips in Chumstick strata) at the south end of

Wenatchee. South of Wenatchee Heights is a huge landslide. The main canyon southwest of Wenatchee is Squilchuck Canyon. The next canyon to the northwest is the site of the Cannon gold mine.

The full width of the Chiwaukum graben is visible between Ohme Gardens (6 miles away) and the base of the Mount Stuart Range (21 miles distant). The graben preserves the following Challis sequences: Swauk Formation at the Cannon mine, Chumstick Formation between Ohme Gardens and Mount Stuart (and uncon-formably overlain by the CRBG of Mission Ridge), and the Wenatchee Formation southwest of the Cannon mine.

Below the viewpoint the disected plateau is capped by Pleistocene sediments on the Chumstick and Wenatchee forma¬tions. The ramp extending from Ohme Gardens northwest up Burch Mountain is the sub-Wenatchee formation erosion surface. The most obvious feature is the east¬ward dip of the CRBG on Mission Ridge. The CRBG clearly dips off the Cascade Range.

170.8 (5.0) Turn left into Fancher Heights development and stay on main road.

171.3 (0.5) Stop at the Pangborn-Herdon Memorial on the left.

STOP 4-10: OVERVIEW OF THE WENATCHEE AREA

Details not discernible at 4-9 can be seen.

Return to Badger Mountain Road.

171.7 (0.4) Badger Mountain Road, turn right toward E. Wenatchee, staying on Badger Mountain Road and North Eastmont.

173.9 (2.2) Turn right (downhill) on 11th St NE in East Wenatchee.

174.6 (0.7) At T-junction, turn right North Baker Avenue.

176.6 (2.1) At T-junction, turn left on 27th Street NE.

176.9 (0.2) At T-junction, turn right (north) on highway.

(1.3) Junction with US 2, turn left (west) for Seattle, which is about a three-hour drive.

END OF DAY FOUR

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