BEDROCK GEOLOGIC MAP, BIOSTRATIGRAPHY, AND STRUCTURE SECTIONS OF THE METHOW BASIN, WASHINGTON AND BRITISH COLUMBIA

by

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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES

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INTRODUCTION

This geologic map (Plates 1-3) and accompanying structural and biostratigraphic summaries (Table 1) are the outgrowth of several years of research by members of the Methow basin studies group at the University of Washington. We have three intentions in publishing these items. The first is to make public the data base upon which the Ph.D. thesis of one of us (MFM) relies. McGroder's thesis involved structural analysis and interpretation of the major folds and faults in the basin (McGroder, 1988). Second, we wish to make public the body of biostratigraphic data from the United States portion of the basin that has accumulated over the years but has remained unpublished. Finally, our study group, which has undertaken such diverse tasks as facies analysis, subsidence analysis, detailed sedimentology and stratigraphy, has felt a need for a basin-wide compilation map that (a) shows our data and all the data of previous workers on one map and (b) forms a base from which basinal isopach, paleofacies, and other maps can be derived. This map satisfies those needs.

Approximately 75 percent of the mapping shown on our map has been taken directly from previous workers, most notably Tabor and others (1968), Staatz and others (1971), Coates (1974), Tennyson (1974), and Barksdale (1975). The remaining 25 percent is from two sources, as follows. In several areas one of us (MFM) has remapped the geology in detail, concentrating on the newly recognized fold and thrust geometry of large-scale structures. Additionally, in many parts of the Pasayten Wilderness (that area of the basin just south of the International border), we have modified previous maps with reconnaissance work of our own (MFM and JIG).

Only in the last few years have we (a) begun to understand the structural geometry of thrust faults within the basin and (b) recognized an important and widespread sub-Midnight Peak Formation unconformity. Some revisions we have made in fault and contact geometry have been influenced by the prejudices we have derived from discovery of these relations. We have not visited all areas where we have made reinterpretations of previous maps. An example of such a revision is the Freezeout fault, which we have interpreted as a steeply dipping thrust fault that duplicates the Harts Pass Formation. While we have not unequivocally demonstrated this structural relation by new mapping, we believe it is the most satisfactory explanation for the greater thickness of that unit in the west side of the basin. Moreover, this interpretation is most compatible with what we now know about the structure of more thoroughly studied areas to the north and south.

Any geologic map is an interpretation of a sum of observations by field geologists. Given the diverse quality of exposure, the remoteness of certain parts of any map area, and the evolution of thought on stratigraphic and structural relations, it stands to reason that interpretations of the geology of an area are bound to evolve and improve through

time. We offer this map as the best representation of Methow basin geology as of 1990. At the end of this text, we discuss several geologic relations that, for one reason or another, are not well understood. Further work in certain areas could promote generation of the next basin synthesis, which will no doubt be an improvement on ours.

DESCRIPTIONS OF MAP UNITS

Subterranes

We subdivide the Methow basin into three subareas (Fig. 1). The central and northern portions of the basin comprise the northern Methow subterrane, whereas the area south and east of the Boesel fault is termed the southern Methow subterrane. Based on what is known about their stratigraphy and age, rocks in the third subarea, west of the Hozameen-North Creek fault, cannot definitively be tied with rocks to the east within the Methow basin. Although we suspect that rocks in the third subarea are correlative with Jurassic to Lower Cretaceous strata within the Methow basin, they are fault bounded, and we cannot rule out the possibility that they are far-travelled with respect to the Methow basin. Hence we treat rocks in the third subarea, i. e., the North Creek Volcanics, independently of the two Methow subterranes in this report.

Figure 2 reconciles our stratigraphic nomenclature for the Methow basin with that of previous workers. Because the *group terminology* used in Canada (Jackass Mountain Group, Pasayten Group, summarized in Coates, 1974) has precedent, we have retained that usage and applied it to rocks south of the International border. However, because Coates (1974) named formations numerically, we have decided to extend the U.S. *formation terminology* (see Barksdale, 1975) into the Canadian portion of the basin. We only correlate strata in this report; formalization of units is not attempted.

The basis for distinguishing the two informally named subterranes is their stratigraphy below the Virginian Ridge Formation. The principle stratigraphic differences are (Fig. 2): (a) In the southern subterrane, the thick and distinctive Jackass Mountain Group is missing. Middle Albian rocks of the Patterson Lake conglomerate and Virginian Ridge Formation lie unconformably above Hauterivian and Barremian strata of the Buck Mountain Formation. (b) In spite of the fact that a locally northward plunge brings stratigraphically deep rocks to the surface in the southern subterrane, no basaltic basement has been recognized there as it has in an area in the northern subterrane just to the northwest of the area in Plate 1. (See Ray, 1986.) (c) Several Late Jurassic to Early Cretaceous plutons are present in the southern subterrane (unpubl. K-Ar data, V. R. Todd, U.S. Geological Survey [USGS], written commun., 1986). Stocks of that age apparently are not present in the northern subterrane. (An exception is the Button Creek stock, but it may be fault bounded.) (d) A marked angular unconformity between probable Jurassic rocks (Twisp Formation) and overlying Upper Jurassic to Lower Cretaceous rocks has been described by Barksdale (1975) from an area in the southern subterrane. In the northern subterrane, units of comparable age are paraconformable (Coates, 1974).

Both subterranes are overlain by Albian strata of the Pasayten Group. On the basis of relations along the Boesel fault, we tentatively interpret the two subterranes to have been tectonically juxtaposed rather than to be facies equivalents of one another. The juxtaposition of the two subterranes took place between deposition of the Harts Pass and

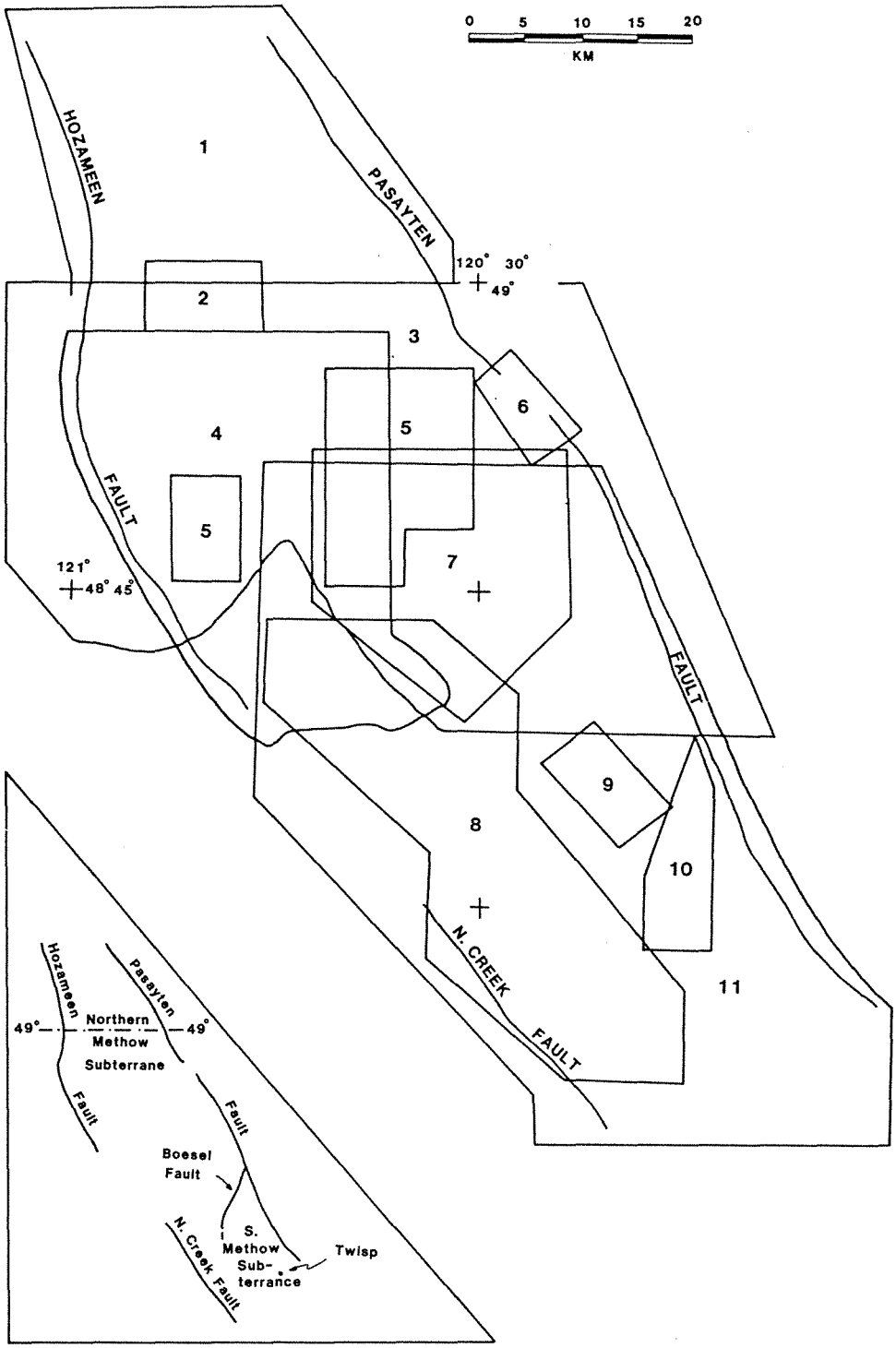

Figure 1. Map of the Methow basin showing subterranes (inset) and sources of map data. 1, Coates (1974); 2, Lawrence (1967); 3, Staatz and others (1971); 4, Tennyson (1974); 5, McGroder, reconnaissance mapping (this report); 6, White (1986); 7, Tabor and others (1968); 8, McGroder, detailed mapping (this report); 9, Riedell (1979); 10, Maurer (1958); 11, Barksdale (1975).

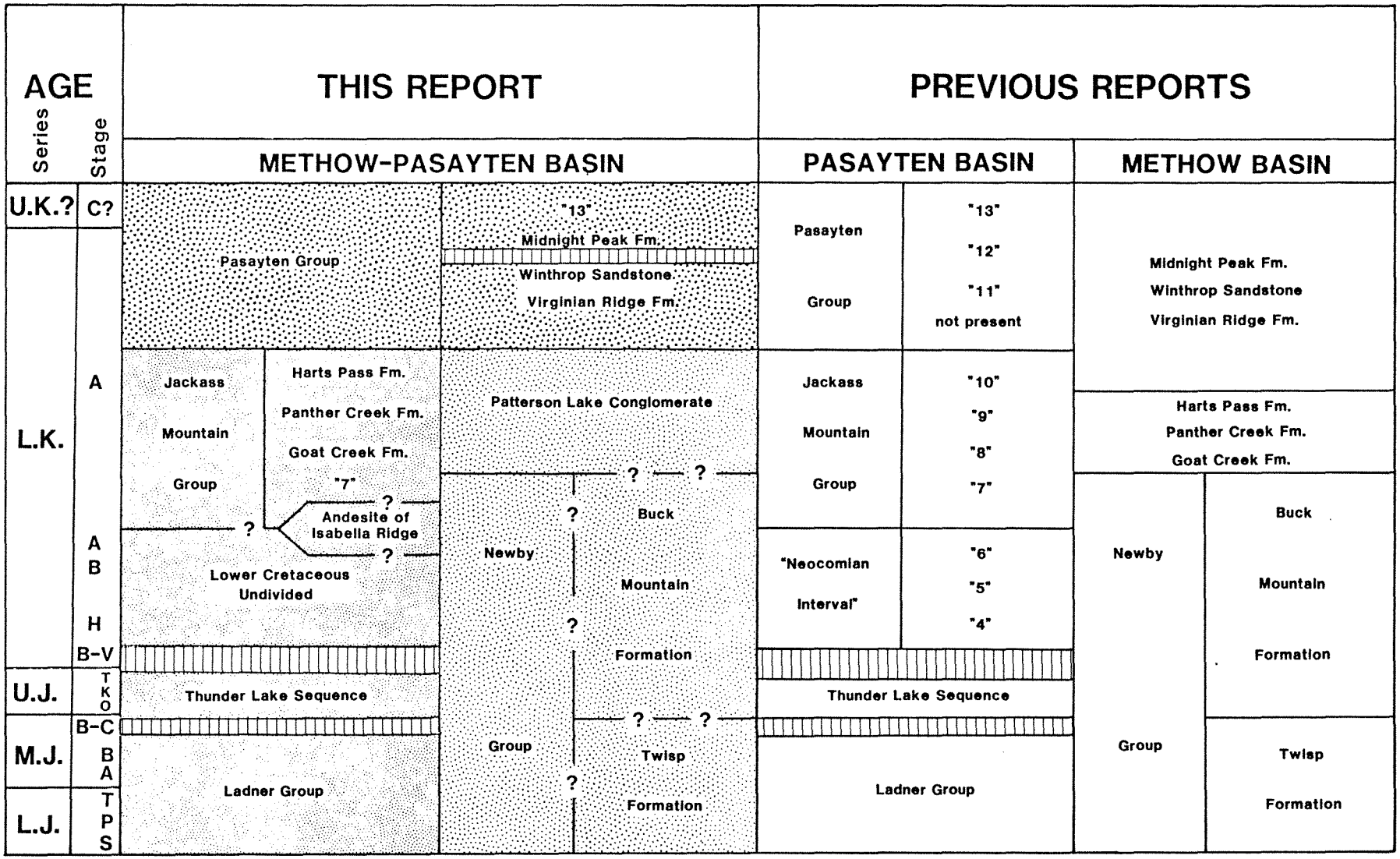

Figure 2. Diagramatic stratigraphic columns and stratigraphic nomenclature for the Methow-Pasayten basin (Methow basin in this report). Cenozoic rocks not shown. Fine stipple, northern Methow subterrane; medium stipple, southern Methow subterrane; coarse stipple, overlap assemblage.

Virginian Ridge Formations, that is, during the early to middle Albian. McGroder (1988) speculated that the southern subterrane may have resided east of the Pasayten fault prior to Albian time.

Intrusive Rocks

Button Creek stock

Barksdale (1975) named this body of biotite-hornblende quartz diorite along the Pasayten fault. K-Ar dates of 150 and 153 Ma on hornblende were obtained by V. R. Todd (USGS, written commun., 1986). These ages call into question the map relations originally reported by Barksdale (1975)--that the stock both intrudes the Buck Mountain Formation and cuts the Ortell Creek fault. The western contact of the pluton is likely depositional and/or faulted; the eastern contact, buried beneath alluvium, is probably the Pasayten fault.

Cretaceous plutonic rocks

This category of rocks includes the Black Peak batholith, Fawn Peak stock, Pasayten stock, Rock Creek stock, and Fraser Creek complex. These bodies generally vary in composition from diorite to granodiorite, but are predominantly quartz diorite (Adams, 1964; Misch, 1966; Tabor and others, 1968; Barksdale, 1975). In most localities, these rocks are clearly intrusive into surrounding country rock, and contact aureoles range from about 10 to more than 1,000 m in width.

These units have been dated (K-Ar) as follows:

Black Peak batholith:
- 98 Ma (hbl), V. R. Todd, USGS, written commun., 1986
- 88 Ma (hbl), Engels and others (1976)
- 73 Ma (bio), Engels and others (1976).

Fawn Peak stock:
- 87 Ma (bio), V. R. Todd., written commun., 1986
- 89 Ma (bio), Riedell (1979).

Pasayten stock:
- 85-88 Ma (bio), Tabor and others (1968).

Rock Creek stock:
- 86 Ma (hbl), Tabor and others (1968).

Fraser Creek complex:
- 130 Ma (hbl), V. R. Todd, written commun., 1986.

Cretaceous and Tertiary stocks, undivided

This map unit comprises several small stocks of varied composition. Their age is determined from local map relations or regional relations only. In most localities, these bodies are intrusive into surrounding rocks.

Tertiary plutonic rocks

This map unit includes the Castle Peak stock, Golden Horn batholith, Lost Peak stock, and Monument Peak stock. These units have been described in detail by Misch

(1966), Lawrence (1967), Tabor and others (1968); Staatz and others (1971), and Barksdale (1975). The Monument Peak and Golden Horn bodies are composed largely of granite that weathers a distinct golden orange color. Abundant N20^{o}E-trending quartz porphyry dikes between the two bodies suggest they are connected at depth. The Lost Peak and Castle Peak stocks range from granodiorite to quartz monzonite and contain both hornblende and biotite. The vast majority of contact relations are intrusive; aureoles are typically very narrow. Dikes from the Monument Peak stock intrude the Lost Peak stock, establishing a relative temporal relation between the two.

K-Ar ages of the plutons are as follows:

Castle Peak stock:

50 Ma (hbl), Tabor and others (1968).

50 Ma (bio), Tabor and others (1968).

Golden Horn batholith:

47 Ma (bio), Tabor and others (1968).

Lost Peak stock:

51 Ma (bio), White (1986).

Monument Peak stock:

48 Ma (bio), Tabor and others (1968).

Stratified Rocks

Below, from oldest to youngest, are brief lithologic descriptions of the volcanic and sedimentary map units shown on Plates 1-3. Following each description we provide information pertaining to the age of the unit, based largely on faunal studies by one of us (VSM). The data are provided in Table 1, and sample locations are shown in Figures 3a through 3d. In some instances, our discussions of ages of units rely on data summarized in older reports (e.g., Barksdale, 1975); some of the specimens referred to in those reports cannot be found in the Burke Museum and are therefore not listed in Table 1. We have not retabulated biostratigraphic data from the Canadian portion of the basin; we refer readers to the excellent summary by Coates (1974).

Table 1 is provided primarily as a tabulation of taxa in the United States portion of the Methow basin. The age designations we give to individual map units are based on (a) comparisons of taxa within the basin with four principal treatises by workers in the United States (Anderson, 1938; Jones, 1960; Murphy, 1956, 1975), and (b) a limited number of comparisons to several treatises by Canadian workers, particularly those of Jeletzky (1971, 1972, 1977, 1984). In particular, a few important Aptian and Albian taxa were compared to Jeletzky's work because rocks of htis age in southern British Columbia are particularly well studied and they are of tectonostratigraphic importance. It is important to point out that the faunal tabulation (Table 1) and age designations included with the unit descriptions do not represent the definitive summary of Methow basin biostratigraphy because we did not synthesize all paleontologic literature in regard to age ranges for all taxa. We recognize that such a summary would be a very important contribution to Methow basin stratigraphy; however, it would require a significantly greater investment of time than we were able to devote for the purposes of our study. We include the faunal list in this report in the hope that interested parties may take it upon themselves to verify or refine our age designations for Methow basin strata.

Southern Methow Subterrane

Newby Group

Newby Formation was the name coined by Barksdale (1948) for deformed and altered andesitic breccias and flows, black shales, and volcanic lithic sandstones on Lookout Ridge, approximately 6 km southwest of Twisp and south of the area described in this report. The unit was subsequently elevated to group status by Barksdale (1975), who felt that the unit was at least locally subdivisible. We apply that name to rocks that crop out in a outcrop belt north of the lower Twisp River and that resemble those originally described by Barksdale. We have abandoned the usage of Newby Group for rocks at the head of the Twisp River and retain the nomenclature of Misch (1966) for those rocks. (See North Creek Volcanics, below.) We have also abandoned the use of the term Newby adjacent to the International border. On the basis of continuity of outcrop, we extend the Ladner Group of Coates (1974) south of the border to encompass rocks that Tennyson (1974) designated Newby Group. In our opinion, it has never been satisfactorily demonstrated that rocks known as Newby Group are laterally equivalent to the Twisp and Buck Mountain Formations. Until more careful mapping and geochronologic work are undertaken on all Newby Group rocks, we allow for the possibility that they are not of similar age and are therefore not equivalent to the Twisp and Buck Mountain formations. The only information pertaining to the age of the Newby Group in the area described in this report is that the unit is depositionally overlain by the Patterson Lake conglomerate (informal) of Albian age.

Twisp Formation

Twisp Formation was the name applied by Barksdale (1975) to a package of complexly deformed, thin bedded, black argillites and green-gray to brown sandstones near Twisp, Wash. Bedding in this unit typically dips steeply and has a highly varied strike. The sandstones are typically volcanic lithic (Cole, 1973).

No diagnostic fossils have been recovered from the unit, but Barksdale (1975) tentatively assigned it a Lower to Middle Jurassic age because of its lithologic similarity to the Ladner Group in southern British Columbia as described by Coates (1970) and Jeletzky (1972). Barksdale (1975) reported that the Buck Mountain Formation (Early Cretaceous, see below) unconformably overlies the Twisp Formation south and east of Winthrop, Wash.

Buck Mountain Formation

Buck Mountain Formation was the name given by Barksdale (1975) to an assemblage of volcanic and volcaniclastic rocks along the east side of the basin from the southern end of the area described herein northward to about the Canadian border. In this report, we restrict usage of that term to rocks at Buck Mountain and rocks that are clearly correlative with rocks there because we are uncertain whether rocks north of the Ortell Creek fault (Plate 2) are indeed correlative with those at the type locality. (See andesite of Isabella Ridge for description of rocks that have been separated out of the Buck Mountain Formation.) At Buck Mountain, Barksdale (1975) described the unit in terms of three informal members, although neither he nor we subdivided the unit on our respective maps. The basal member consists of andesitic breccias, minor fine-grained clastic rocks, and a few andesitic flows that are commonly massive. The thick middle member consists of lithic sandstone, siltstone, black shale, and lenticular conglomerate

beds as much as 275 m thick. The conglomerate is composed predominantly of clasts of dark-colored andesite, chert, dike rocks, and minor limestone. Granitoid boulders are found in conglomerates at higher stratigraphic levels within this member. The upper member contains volcanic lithic sandstone, siltstone, and black shale; no conglomerate is present in this part of the section.

The layered volcanic and volcaniclastic strata of the Buck Mountain are the oldest fossiliferous beds in the Methow basin south of the international border. The three informal members described by Barksdale (1975) are not only lithologically distinct but also have different paleontologic characteristics.

> Unit one: The lowest fossils found in this volcanic and volcaniclastic unit include the belemnite *Acroteuthis* cf. *A. impressa* Anderson, according to Barksdale (1975). This species cannot be located in the Burke Museum collection and is therefore not listed in Table 1. This belemnite is probably of Neocomian age (Berriasian-Barremian). While the belemnites are not very age-specific, it is likely that the lower Buck Mountain is at least in part Lower Cretaceous.
>
> Unit two: These volcaniclastic marine strata contain the ammonites *Shasticrioceras hesperum* and *S. poniente*, as well as pelecypods *Inoceramus colonicus*, *Periplomya trinitensis*, and *Pleuromya papyracea*, and two belemnites *Acroteuthis aboriginalis* and *A. shastensis*. Although *Shasticrioceras* sp. is found in Hauterivian and Barremian strata, *S.* cf. *S. poniente* is considered by Jeletzky (1971) to be a diagnostic Barremian fossil in strata in the Canadian Cordillera. The other species are characteristically Hauterivian in age in California, Oregon, and Alaska (Imlay, 1961). It seems likely that this unit is Hauterivian and Barremian in age.
>
> Unit three: The upper unit in the Buck Mountain Formation contains *Hoplocrioceras remondi*, and *Ancycloceras ajax* which occur in beds in California at higher horizons than the *Shasticrioceras*, but probably within the Barremian.

The Buck Mountain also contains numerous *Buchia* sp. according to Maurer (1958), but these specimens are not discussed in Barksdale's (1975) summary of the age of the unit. These pelecypod fossils are of general Oxfordian to Valanginian age (Jeletzky, 1984). *Buchia piochii* (locality WA-549) is Tithonian in age (Jeletzky, 1984), but paradoxically, it is found between beds that contain *Shastacrioceras* sp., a Hauterivian to Barremian ammonite (Maurer, 1958). The ammonites suggest that Maurer's locality WA-549 lies within Barksdale's middle member. We tentatively ascribe the presence of the *Buchia* spp. to reworking but point out that this dilemma represents an important unresolved problem within the basin.

In sum, the upper two units in the Buck Mountain Formation are Hauterivian to Barremian, possibly middle or upper Hauterivian to middle Barremian. The age of the lower portion of the Buck Mountain Formation is imprecisely known; belemnites suggest it is Neocomian. The occurrence of reworked(?) *Buchia* spp. within rocks that are probably Hauterivian-Barremian in age may signify that the rocks lying with angular discordance beneath the Buck Mountain near Winthrop, Wash. (Barksdale, 1975) at one time contained Upper Jurassic strata and that they were deformed and eroded in Berriasian or Valanginian time. Deformation of this age has not been recognized elsewhere in the Methow basin.

Patterson Lake conglomerate (informal)

This newly designated unit has most recently been included in the Virginian Ridge Formation by Barksdale (1975) and Trexler (1985), although it had earlier been broken out as a separate unit by Maurer (1958). It has been broken out in this report because (a) it has a distinctly different clast composition and internal stratigraphy from that of the typical Virginian Ridge, and (b) it is mappable and apparently has sharp contacts with overlying (Virginian Ridge Fm., sensu stricto) and underlying rocks. The unit is internally heterogeneous and contains conglomerate, sandstone, and black to red mudstone. The vast majority of conglomerate clasts are clastic sedimentary rock fragments (Trexler, 1984); Virginian Ridge-type chert clasts are sparse or absent. The sandstones range from volcanic lithic to arkosic (Trexler, 1984). We have included in the Patterson Lake some sandstones and shales that Barksdale (1975) previously mapped as Goat Creek Formation and Twisp Formation. One outcrop of note is at the base of the Patterson Lake unit near the western bend in the Elbow Coulee Road (topographic point 3023, SE1/4 sec. 29, T34N, R21E, Plate 3). There, a boulder conglomerate with clast sizes ranging up to a meter is preserved. This deposit is significant in that it may record local syndepositional faulting. The Patterson Lake conglomerate is quite distinctive, yet its heterogeneity has caused it to be mapped differently by a number of workers. Also, many of the fossils originally used to date the Virginian Ridge Formation actually were recovered from the Patterson Lake unit. For these reasons and because the Patterson Lake conglomerate appears to record syndepositional tectonism and directly underlies a regional overlap succession (Pasayten Group, Fig. 2), we believe that there are important reasons for the lithostratigraphy and biostratigraphy of the unit to be studied in greater detail than it has been to date.

Two trigonids reported by Barksdale (1975) from what we now call the Patterson Lake conglomerate (not listed in Table 1 or on Fig. 3 because they could not be located in the Burke Museum), *Trigonia* cf. *T. maudensis* and *T.* cf. *T. diversicostata*, commonly are found occur in Aptian-Albian age strata. A more age diagnostic ammonite in the Patterson Lake is *Brewericeras* (=*Beaudanticeras*) *haydeni* of Albian age. Murphy and Rodda (1960) reported that the first occurrence of *Beaudanticeras haydeni* in California is probably in the middle Albian. They also reported that *B. haydeni* occurs with *Mortoniceras* in California and so it probably ranges into the late Albian (Jeletzky, 1977). However, because of the substantial thickness of Albian strata above the Patterson Lake conglomerate (see below), it seems most likely that this unit is middle Albian.

Northern Methow Subterrane

Ladner Group

The Ladner Group consists of varied proportions of fine-grained marine clastic rocks and volcanic sandstone, and minor volcanic breccias and conglomerates (Coates, 1974). Andesitic lavas occur in the top of the section (Coates, 1974; O'Brien, 1986). Fine-grained clastic rocks predominate in many areas and are typically composed of thinly interbedded siltstone and black slate. Coarse wood debris is locally abundant. The section is fossiliferous and ranges in age from Sinemurian to Bajocian (Coates, 1974; O'Brien, 1986).

Thunder Lake sequence

The nomenclature of this unit has had a complicated history. That history was recently summarized and the unit informally renamed by O'Brien (1986), whose nomenclature we use. The sequence crops out as a thin belt along the western side of the basin in Manning Park, B. C. It has not been recognized in this outcrop belt directly south of the International border, but that part of the basin is in a remote area and has not received detailed stratigraphic attention. Strata of similar age may have been deposited near Buck Mountain, in the eastern Methow basin, but they apparently were eroded in the Early Cretaceous based on our interpretation that Hauterivian-Barremian strata there contain reworked *Buchia piochii*. The Thunder Lake unit consists largely of fine-grained, well sorted sandstone interbedded with subordinate sandy argillite that is typically fossiliferous (Coates, 1974). Its age is Oxfordian through Tithonian (O'Brien, 1986), and it unconformably overlies the Lower to Middle Jurassic Ladner Group. The Thunder Lake unit is difficult to distinguish from overlying Lower Cretaceous strata (Coates, 1974).

Lower Cretaceous, undivided

In this analysis, we have grouped poorly dated Lower Cretaceous units that had been informally named the Pitophyllum beds (map unit 4) and the Copper Creek assemblage (map unit 6) by Coates (1974). Both of Coates' units crop out only in isolated exposures along faults, and their original stratigraphic relations to other units in the basin are not known. Both outcrop belts contain conglomerates dominated by volcanic clasts. Varied proportions of finer grained clastic rocks are also present. Neither outcrop belt contains diagnostic megafossils, although floras from the western outcrop belt may be Neocomian and/or Albian in age. (See Coates, 1974.)

Andesite of Isabella Ridge (informal)

We have subdivided Barksdale's (1975) Buck Mountain Formation because we believe there are significant stratigraphic and lithologic differences between two isolated outcrop belts and we are not able to confidently establish that units beneath the Pasayten Group overlap succession can be correlated between the northern and southern Methow subterrane. In particular, the rocks in the Isabella Ridge unit are almost exclusively andesites and andesite breccias and are at least 1,300 m thick (Dixon, 1959), whereas those at Buck Mountain are predominantly fine-grained clastic rocks. Rocks at Buck Mountain contain abundant marine fossils; rocks of the Isabella Ridge unit were probably deposited in terrestrial environments. Although we adopt the conservative approach of separating the two outcrop belts, we cannot rule out the possibility that they are in part facies equivalents of each other. We retain the informal name "andesite of Isabella Ridge" of Dixon (1959) for the northern outcrop belt of rocks previously assigned to the Buck Mountain Formation. Most breccias and flows are porphyritic and have abundant phenocrysts of plagioclase and augite and very minor magnetite and hornblende. The age of this unit is not known. It probably underlies the Goat Creek Formation (Barksdale, 1975), although Dixon (1959) interpreted the contact with the Goat Creek (his Sweetgrass formation) as a fault. The andesite of Isabella Ridge may be an eastern equivalent of map unit 7 (Coates, 1974, and this report), but positive correlation will not be justified until the age of the andesite is known with better precision.

Unit 7

This unit was informally referred to as the *Inoceramus colonicus* beds by Coates (1974), from whom this description is taken. The unit is composed predominantly of massive sandstone with minor gravelly lenses and shales. It contains abundant *Inoceramus* clams. The unit ranges in age from Hauterivian to lower Barremian (Coates, 1974).

Goat Creek Formation

We have grouped map unit 8 of Coates (1974), the lower Panther Creek Formation of Tennyson (1974), and the Goat Creek Formation of Barksdale (1975) into this unit because they all occupy the same stratigraphic position, are roughly equivalent in age, and resemble one another lithologically. North of the International border, the unit is composed largely of dark-gray quartzofeldspathic sandstone and gray siltstone (Coates, 1974). At the type locality in the eastern Methow basin, Barksdale (1975) described the unit as well-bedded, coarse- to fine-grained arkose and black argillite. In Canada the unit is Barremian to lower Albian (Coates, 1974); no fossils have been recovered in the U.S. portion of the basin.

Panther Creek Formation

The Panther Creek is perhaps the most distinctive and easily recognizeable unit in the basin, in part because it holds up many of the higher ridges in the area. It is most readily characterized as granitoid- and volcanic-cobble conglomerate, although the percentage of coarse clastics may be subordinate to that of sandstone and shale at any given locality. The unit is widespread and grossly tabular in map pattern. In some local exposures, however, the conglomerates appear to occupy large-scale lenticular channels.

In the U. S., a number of pelecypod species have been identified, among them *Megatrigonia* cf. *M. condoni* (Packard) and *Pterotrigonia oregona* (Packard) (Barksdale, 1975). [Barksdale reported that these fossils were collected at the type locality of the unit at the head of Panther Creek (Plate 2), but they are not present in the Burke Museum and so are not listed in Table 1 or Fig. 3.] These species are commonly found in Aptian-Albian strata. *M. condoni* is known to occur in strata as young as Cenomanian. Other pelecypods listed by Barksdale (1975) were *Anchura biangulata* (Anderson) and *Ampullina avellana* (Gabb) which commonly are found in strata of late Hauterivian age elsewhere. It is not clear whether the *Anchura* and *Ampullina* are (1) reworked from the Buck Mountain, (2) recovered from a conglomeratic facies in the Buck Mountain Formation with granitic clasts and has therefore been confused with the Panther Creek Formation, or (3) indicative of a late Hauterivian age for part of the Panther Creek; we favor one of the first two alternatives. *Turbo festvus*, a late Hauterivian ammonite, was recovered at locality B1368, but we suspect it may have been collected from the Buck Mountain Formation rather than the Panther Creek and therefore do not consider it diagnostic.

The age of the Panther Creek Formation is thus only broadly constrained in the U.S. to the late Hauterivian to Albian. Well-dated and stratigraphically continuous upper lower and middle Albian strata overlie the Panther Creek Formation, thus constraining its age to late Hauterivian-early Albian. In Manning Park lithologically similar conglomerates are lower lower Albian (Unit 9a of Coates, 1974).

Harts Pass Formation

The Harts Pass Formation was named by Barksdale (1975) for the prominent sandstone exposures near Harts Pass, Wash. In this report, we have included with that unit the clastic rocks of map unit 10 (uppermost Jackass Mountain Group) of Coates (1974) based on similarity of age and lithology and continuity of outcrop. The unit is composed of roughly equal proportions of thick-bedded sandstone and thinner bedded siltstone and shale. The sandstones are quartzofeldspathic and weather white or buff. Fine-grained rocks are typically gray to black and locally contain ammonites. The unit is roughly 8,000 ft. (2,400 m) thick and underlies a vast area in the western reaches of the basin (Plates 1, 2).

The marine arkoses and shales of the Harts Pass Formation depositionally overlie the Panther Creek Formation. The Harts Pass contains the following fauna: *Douvilleiceras* cf. *D. mammillatum* (Schlothiem), *Puzosia* cf. *P. sharpei*, *Melchiorites* cf. *M. shastensis*, *Hamites* cf. *H. attenuatus*, *Hypophylloceras* cf. *H. onoensis*, and *Cheloniceras* sp. among ammonoids. *Douvilleiceras* is restricted to the Albian here and elsewhere in the southern Canadian Cordillera (Jeletzky, 1977). However, the presence of *D.* cf. *D. mammillatum* (Schlothiem) suggests an approximate correlation to the *Brewericeras heulenense* ammonite zone and is therefore upper lower Albian (of the European standard) in part (*sensu* Breistroffer, 1947; see Jeletzky, 1977). *Cheloniceras* is known from the upper Aptian, *Hamites attenuatus* is from the upper Aptian through the upper Albian, and *Melchiorites* is from the lower Aptian into the lowest Albian.

The bulk of the Harts Pass Formation appears to be Albian, possibly as young as middle Albian; there is no indication of any upper Albian. Parts of the formation may be as old as late Aptian (*Hamiticeras*), but stratigraphically lower strata (basal Harts Pass Formation) contain *Puzosia*, which is Albian. The presence of *Gastroplites canadensis* Whiteaves suggests a middle Albian age for at least part of the Harts Pass Formation (Jeletzky, 1971). A late Aptian to middle Albian age seems likely for the Harts Pass Formation. Accounting for the fact that the underlying Panther Creek Formation is lower Albian in Canada, we surmise that the Harts Pass Formation is early to middle Albian in age.

Overlap Assemblage

Virginian Ridge Formation

The Virginian Ridge Formation was named by Barksdale (1948) for distinctive chert-lithic sandstone, shale, and conglomerate largely of marine origin west and northwest of Winthrop, Wash. The unit was subdivided by Tennyson (1974) into a conglomeratic and a shaly lithofacies. More recently, the unit has been characterized in greater detail by Trexler (1985), who recognized three members: a basal nonmarine to marine clastic package that includes heterolithic conglomerate (Patterson Lake conglomerate in this report), a sandstone-shale package that he termed the Slate Peak member, and a chert-conglomeratic unit that he called the Devils Pass member. In this report, the Virginian Ridge has been subdivided into three rock types that reflect solely the percentage of chert-rich conglomerate in any given local section. Kvr1 refers to fine-grained clastics that contain <10 percent conglomerate, Kvr2 refers to parts of the section that contain 10-40 percent conglomerate, and Kvr3 refers to sequences that are composed of >40 percent conglomerate. These rock types do not represent members in the formal

stratigraphic sense because Kvr2 is present at two levels in the section in the western outcrop belt. (Alternatively, Kvr3 could be considered a tongue that extends from the west into the middle of Kvr2.) Kvr1 is roughly equivalent to the lower part of Tennyson's (1974) fine-grained portion of the formation and to turbidites described from the basal part of the Devils Pass section by Trexler (1984). Kvr2 is roughly equivalent to the Slate Peak member of Trexler (1985) and to parts of both the fine-grained and coarse-grained facies of Tennyson (1974). Kvr3 is roughly equivalent to the Devils Pass member of Trexler (1985) and to the upper (most conglomeratic) part of Tennyson's (1974) coarse-grained facies. Although the unit as a whole is distinguished by its content of chert detritus, some parts of the section contain abundant quartzofeldspathic sand (Cole, 1973; Trexler, 1984), especially those exposures in the central and eastern outcrop belts. The Virginian Ridge Formation does not crop out in the Manning Park area north of the International border for two reasons: (a) uplift of rocks west of the Chuwanten fault has unroofed the upper part of the section and nothing younger that the Harts Pass Formation is preserved there, and (b) the eastern tongue of the formation, which lies between the Harts Pass and Winthrop Formations in the U.S. part of the basin, apparently did not extend very far east in the Canadian portion of the basin, leaving the Winthrop to lie directly atop the Harts Pass. We consider the Virginian Ridge to represent the base of an overlap sequence because it clearly lies depositionally atop the youngest units in both the northern and southern Methow subterranes (Trexler, 1985), and the underlying units within the subterranes cannot be conclusively shown to be correlatives.

The Virginian Ridge Formation as defined in this report contains few age-diagnostic fossils. *Pteritrigonia oregona* is commonly found in Aptian-Albian age strata; *Megatrigonia* cf. *M. condoni* is found in Aptian-Cenomanian strata. (These taxa are listed in Barksdale, 1975, but not here because the fossils are not preserved in the Burke Museum.) Because the Virginian Ridge locally overlies the Patterson Lake conglomerate and overlies the Harts Pass Formation in many places, it is probably no older than middle Albian. Because it underlies the Winthrop Sandstone in many places, it is probably no younger than late Albian.

Winthrop Sandstone

The name of this unit originated with Russell (1900), who applied it to a continental assemblage of nearly white, massive arkosic sandstones and light-gray shales northwest of Winthrop, Wash. (Barksdale, 1975). Most sandstone beds contain trough cross-beds, which allow the Winthrop to be distinguished from the petrologically similar but older Harts Pass Formation. Abundant wood fragments and minor coal are also present in the Winthrop. The base of the unit is in many places gradational with the Virginian Ridge Formation, and in the central portion of the basin the two are thoroughly intermixed (see Virginian Ridge-Winthrop, undivided, below). The top of the unit is an unconformity at every location where we have confidently identified the contact. Previous workers assigned red arkosic sandstone at the top of the Winthrop to the lower part of the Midnight Peak Formation and therefore deduced that the contact was gradational. More recently, the criteria for distinguishing the two formations have been revised (D. Mohrig, Univ. of Washington, oral commun., 1986), and in this report we use sandstone composition rather rock color to separate them. The Winthrop is several times thicker in its eastern outcrop belt than it is in the west for two reasons: (1) it interfingers the Virginian Ridge Formation (Trexler, 1985), and (2) the erosion represented by the angular unconformity at the top of the Winthrop was localized west of the main eastern outcrop belt of the Winthrop. A new lithology has been recognized

in the Winthrop in its western outcrop belt: interbedded volcaniclastic sandstone, fine-grained crystal-lithic tuff-breccias, minor lavas, and arkosic sandstone. The volcanic breccias differ from those in the Midnight Peak in that the former are finer grained and more heterolithic; they contain such diverse lithologies as olivine basalt, chert pebbles, argillite chips, and vein quartz. This volcanic lithic unit was originally included in the Midnight Peak Formation by Barksdale (1975). (In fact, these rocks underlie the type locality of that unit - Midnight Mountain.) We have included the volcanic unit in the Winthrop Sandstone because the volcanic rocks are clearly interbedded with feldspathic sandstone on both the outcrop and map scales. The unit is denoted on the map with triangle patterns (see Plates 2, 3). It is possibly a lateral equivalent of volcanic breccias reported from near the top of the Virginian Ridge by Trexler (1984).

On the basis of floral data summarized by Coates (1974) and Rau (1987), the Winthrop Sandstone is Albian in age, and probably middle to late Albian because it overlies lower and middle Albian rocks. Rau's floral list is reproduced in Table 1; we include it although we have not had access to the specimens. No age-diagnostic flora younger than Albian has been identified from the Winthrop Sandstone.

Virginian Ridge-Winthrop, undivided

This new map unit is laterally equivalent to the Virginian Ridge Formation plus the Winthrop Formation. North of Slate Peak, Wash., it becomes difficult to distinguish arkosic sandstone with a minor chert-lithic component from chert-lithic sandstone and conglomerate with a minor arkosic component, and so we lump the two units. Previous workers (Tennyson, 1974; Barksdale, 1975) assigned these problematic rocks to one formation or the other, but we believe assignment to either yields misleading map relations. The reason that sediment from two distinctly different source terranes became intermixed at this location has not been explained, but it is reasonable to assume that this mixing took place in the depositional center or axis of the basin. Lithologically, the map unit as we define it is composed largely of thick-bedded sandstone with shale interbeds of varied abundance and thickness. The sandstone is predominantly quartzofeldspathic, but it is locally intercalated with chert-pebble conglomerate and chert-lithic sandstone. Sandstone beds vary from structureless to parallel-laminated to locally cross-bedded; the abundant, large trough cross-beds so characteristic of more typical Winthrop are less common in the sandstones of this composite unit.

No fossils have been recovered from this unit, but because of its assumed equivalence to the Virginian Ridge and Winthrop Formations, it is probably middle to late Albian. It is gradationally overlain by Winthrop Sandstone (senso stricto).

Midnight Peak Formation

Barksdale (1948) gave the name Midnight Peak Formation to a suite of andesitic volcanic rocks and red clastic rocks that are exposed in and west of the Methow Valley in Washington. In this report, we have restricted the usage somewhat in the U.S. portion of the basin because we now assign certain volcanic rocks in the western part of the basin to the Winthrop Sandstone (see above). We have also extended the usage to rocks in Manning Park, B.C., that Coates (1974) termed map unit 12. We recognize that the rocks in Canada do not contain the thick pile of andesitic volcanic rocks that characterizes much of the Midnight Peak in the U.S., but the red mudstone, sandstone, and conglomerate in the two areas are indistinguishable and occupy the same stratigraphic positions. Those red clastic rocks were originally named for the mining

town of Ventura by Russell (1900), and Barksdale (1975) retained the name, calling them the Ventura Member of the Midnight Peak Formation. We prefer to treat the Ventura as an informal member because it is clearly interbedded with the andesitic volcanic rocks in several areas of the basin. The sandstones of the Ventura are rich in lithics and feldspar. Ventura conglomerate, although rich in chert, is much more heterolithic than typical Virginian Ridge conglomerate, and it contains clasts that were derived from underlying Methow units. We have identified chert-pebble conglomerate clasts that were undoubtedly derived from the Virginian Ridge Formation, biotite-rich arkosic sandstone clasts that were probably derived from the Winthrop Sandstone (although they might be from the Harts Pass), silty limestone clasts with abundant *Buchia crasicollis* shell debris (source unknown because Valanginian strata have not been recognized in the Methow basin), and granitoid boulders of unknown derivation. The size of the sandstone boulders is perceptibly larger where the angular unconformity above the underlying Winthrop Sandstone is most pronounced. We now know that the Ventura rocks were derived from the west (D. Mohrig, 1986, oral commun.), not from the east as originally stated by Cole (1973). The andesitic volcanic rocks that make up the majority of the Midnight Peak south of the International border underlie many of the higher mountains in the southern end of the basin. Lithologically, the volcanic rocks are fairly homogeneous and are most commonly pyroxene plagioclase andesite breccias and flows. They typically weather various shades of green, purple and red.

The Midnight Peak Formation has not been dated directly. It is unquestionably younger than the Winthrop Sandstone, which contains Albian floras, and it is cut by the Fawn Peak stock which has yielded a K-Ar age on biotite of 89 Ma (Riedell, 1979).

Unit 13

This name was given by Coates (1974) to the stratigraphically highest unit in the Pasayten Group in eastern Manning Park, B.C. It has not been recognized elsewhere. Coates (1974) describes it as poorly sorted, weakly indurated sandstone and conglomerate. Clast lithologies in the conglomerate include granitoid, gneiss, green sandstone, graywacke, chert, volcanics, and quartz. Large, angular blocks of shale and fragments of wood were also noted by Coates (1974). The sandstone is rich in feldspar and lithics and has subordinate quartz and mica.

The age of this unit is unknown. In Manning Park, it overlies red beds that lie at the base of the Midnight Peak Formation elsewhere. The lateral relation of unit 13 to the volcanic portion of the Midnight Peak is not clear.

Cenozoic Deposits

Pipestone Canyon Formation

Pipestone Canyon Formation was the name applied by Barksdale (1975) to a section of granitic-, chert-, and volcanic-clast conglomerate, arkosic sandstone, and thin interbeds of siltstone and shale in Pipestone Canyon, approximately 8 km northeast of Twisp. Barksdale (1975) reported that the largest conglomerate clasts are of granitoid and gneissic composition and range up to 5 ft. in diameter. The clast size diminishes upward, and fine-grained, fossiliferous clastic rocks predominate high in the section.

Leaves, cones, and wood are preserved in the fine-grained deposits, for which Barksdale (1975) reported a Paleocene age. However, the age determination was based on Cenozoic species ranges defined by La Motte in 1952; further work is required before the Paleocene age can be substantiated.

Volcanic rocks of Island Mountain

This unit is localized along the Pasayten fault and has most recently been studied and described by White (1986). She noted that the volcanic rocks range in composition from rhyolite to basalt, and she subdivided the unit into (from oldest to youngest): (1) arkosic sediments, (2) interbedded rhyolitic to andesitic breccias, tuffs, and flows, (3) andesite and basalt flows, (4) intrusive basalt, and (5) dacite porphyry dikes. These units have been grouped together in this report.

White (1986) obtained K-Ar biotite ages of 44 and 47 Ma and fission track ages of 45, 46, and 48 Ma on zircon from the volcanic rocks of Island Mountain.

Quaternary sediments, undifferentiated

This unit includes most major accumulations of unconsolidated alluvial and glacial material in the map area. We have not subdivided the alluvium, and in many locations the bedrock-alluvium contact has been located only very approximately. Interested readers should refer to Waitt (1972) for a discussion of the glacial history of the Methow Valley and surrounding areas.

Other Stratified Rocks

North Creek Volcanics

Misch (1966) applied the name North Creek Volcanics to an assemblage of andesitic lavas and interbedded arkosic sandstones that occur east of the old mining town of Gilbert at the head of the Twisp River. Barksdale (1975) referred to these rocks as part of the Newby Group, but we have chosen to use the terminology of Misch (1966) for two reasons: (1) The term Newby Group has been applied so widely and loosely to poorly dated volcanic and volcaniclastic strata in the Methow basin that it has lost much of its meaning. We retain that term only for rocks at the type locality as described by Barksdale (1975) and for rocks that are demonstrably equivalent to those at the type locality. (2) We have identified a previously unrecognized fault bounding the east side of the North Creek Volcanics outcrop belt. This fault, which we term the North Creek fault, is likely the extension of the Hozameen and Foggy Dew faults (Plates 1-3). The regional extent of this structure makes any correlation of rocks across it tenuous. The andesites in the North Creek unit contain abundant hornblende, but like much of the unit, the primary mineralogy has been obscured by greenschist-facies metamorphism. Metamorphic minerals include chlorite, calcite, albite, epidote, white mica, quartz, actinolite, and, locally, biotite. The sandstones are feldspathic to lithic. Minor pebble conglomerates, fragmental volcanic rock types, and argillites also are found in the North Creek unit.

No fossils have been recovered from the North Creek Volcanics, and the only age constraint on the unit is that it is intruded by the Late Cretaceous Black Peak batholith.

CONCLUDING REMARKS

We conclude by making note of several areas or problems where detailed mapping and stratigraphic analysis will improve or clarify understanding of the map relations and ultimately the geologic history of the Methow basin.

(1) The area southeast of the Boesel fault. In particular, we are uncertain how widely distributed the Patterson Lake conglomerate is and if it can be confidently distinguished from parts of the Twisp Formation, Goat Creek Formation, and Virginian Ridge Formation (sensu stricto). We have taken the conservative approach of dividing rocks below the Pasayten Group into two subterranes but cannot rule out the possibility that the Patterson Lake conglomerate is laterally correlative with the Harts Pass Formation. Insights gained from further analysis of the Patterson Lake unit may also clarify structural relations and the history of movement between the northern and southern Methow subterranes.

(2) The western Methow basin. Because of its remote location, detailed mapping has not been undertaken in the westernmost part of the basin. Mapping is needed in the area between Mount Ballard and Majestic Mountain and the area between the Castle Peak stock and the Hozameen fault.

(3) Southern extent of the Chuwanten fault. The extent and structural geometry of the southern end of the Chuwanten fault are not known with certainty. In particular, the area between Holdover Ridge and Osceola Peak should be examined in greater detail than has been done to date.

(4) Distribution, age, and correlation of the "Newby Group". The term Newby Group has been loosely applied to many undated volcanic and volcaniclastic strata deep in the Methow section. There is reason to believe that many of the units bearing that name are not correlative with one another. The age and internal stratigraphy of the Newby at the type locality have not been established, and we believe it is premature to correlate the Newby with a variety of units in widely separated areas.

(5) Age and lateral extent of the Buck Mountain Formation. Two questions pertain to the Buck Mountain: (a) What is the true stratigraphic relation of the *Shastacrioceras* sp.-bearing beds to the *Buchia piochii* beds? The known ranges of these two fossils make us doubt that the two are interbedded as indicated by Maurer (1958). We tentatively suggest that the *Buchia* pelecypods are reworked. (b) Are rocks herein termed "andesite of Isabella Ridge" correlative with the Buck Mountain Formation? What is the age of the andesite?

(6) Age and correlation of the North Creek Volcanics. The magnitude and sense of displacement on the Hozameen-North Creek-Foggy Dew fault are not precisely known. The displacement history on that fault could be further constrained if one could show that the North Creek correlates with rocks in the lower Methow sequence (e.g., volcanic portion of the Ladner Group; see O'Brien, 1986).

(7) Distribution of units in the east-central part of the basin. The area between Tatoosh Buttes and the Pasayten fault, from the International border to the south as far as Isabella Ridge, has been mapped only in reconnaissance. The distribution of units and geologic structure in this area are poorly known.

(8) Age of the Panther Creek Formation. Based on mapping and biostratigraphic analysis to date, the U.S. portion of the Panther Creek may be as old as upper Hauterivian. Lithologically similar strata in Canada are well dated as lower Albian. We suspect that conglomerates in the Panther Creek and Buck Mountain Formations may have been confused by previous mappers, but further work is needed to resolve this problem.

Table 1: FAUNAL AND FLORAL LISTS FOR THE METHOW VALLEY AREA

While it was beyond the scope of this study, we recognize the importance of undertaking the task of comparing all the taxa in the following table with the most current biostratigraphic literature for the purpose of most precisely defining ages for Methow strata. We put forth this fossil list to allow others the opportunity to verify or revise the ages of Methow strata.

All identifications in the following faunal and floral lists are by V. Standish Mallory unless otherwise noted. The collections are in the Geology and Paleontology Division of the Burke Washington State Museum, University of Washington, Seattle, WA. These lists contain only the macrofaunas that have been collected in the Methow Valley from 1954 to 1988. See Coates (1974) for fossil lists from strata north of the International border. Numbers in parentheses following species name indicate multiple specimens. Fossil localities can be found on Figures 3A-D. Unid., unidentifiable fragments.

Twisp Formation

Locality	Fossil
A2025	fish scale
A4471	cycad leaves
A4482	belemnite
A4559	belemnite

Buck Mountain Formation

Specimens from localities A0549-A0563 are described in Maurer (1958). Maurer designated those localities WA-549 - WA563.

Locality	Species
A0549	*Buchia piochii* Gabb *Pinna* cf. *P. quadrifons* Cragin *Inoceramus concentricus* Parkinson ? *Hamites* spp. *Shasticrioceras* cf. *S. hesperum* Anderson
A0550	*Cylindroteuthis* cf. *C. baculus* Crickmay
A0551	*Lytoceras batesi* (Trask) *Hamites* spp.
A0556	*"Rhynchonella"* spp.
A0557	*Buchia piochii* (Gabb) *Trigonia* sp.
A0563	*"Rhynchonella"* spp.
A0956	*Inoceramus colonicus* Anderson
A2000	Unid.

Buck Mountain Formation (Cont'd)

Locality	Species
A2001	*Inoceramus colonicus* Anderson
	Inoceramus ovatoides Anderson (2)
	Pleuromya papyracea Gabb
	Pecten complexicosta Gabb
	Acroteuthis cf. *shastensis* Anderson
	Acroteuthis sp.
	Shastacrioceras sp.
A2002	*Inoceramus ovatoides* Anderson
	Inoceramus colonicus Anderson
	Acroteuthis cf. *shastensis* Anderson
	?Acroteuthis sp.
	belemnite phragmacone
A2003	*Inoceramus ovatoides* Anderson
	Inoceramus colonicus Anderson
	Inoceramus concentricus Parkinson
	?Leda glabra Stanton
	ostracod
	plant fragments
A2004	*Inoceramus colonicus* Anderson
	Inoceramus ovatoides Anderson
	?ostracod
A2005	*Shasticrioceras hesperum* Anderson
	Inoceramus sp.
A2006	*Pleuromya* cf. *P. papyracea* Gabb
	Lytoceras sp.
A2007	*Shasticrioceras hesperum* Anderson
	Inoceramus ovatoides Anderson
	Inoceramus colonicus Anderson
	?Arca sp.
	Pecten? operculiformis Gabb
A2008	*Inoceramus colonicus* Anderson
	Inoceramus ovatoides Anderson
	Ostrea sp.
A2010	*Inoceramus colonicus* Anderson
	Inoceramus ovatoides Anderson
	Nucula gabbi Stanton
	Entolium operculiformis (Gabb)
	Acroteuthis shastensis Anderson
	Acroteuthis aboriginalis Anderson
	Acroteuthis sp.
	Phylloceras umpquanum Stanton
	Phylloceras sp.
	Shasticrioceras sp.
	?Acrioceras sp. (2)
	Lytoceras cf. *L. aulaeum* Anderson

Buck Mountain Formation (Cont'd)

Locality	Species
A2012	*Inoceramus colonicus* Anderson
A2013	*Shasticrioceras hesperum* Anderson (2) *Shasticrioceras* sp. *Nucula storrsi* Stanton *?Acrioceras* sp. *Corbula? persulcata* Stanton *Inoceramus* sp.
A2014	*Shasticrioceras hesperum* Anderson *Shasticrioceras* sp. *Crioceras latum* Gabb *Siliqua oregonensis* Gabb *Pleuromya papyracea* Gabb *Phylloceras* sp. *?Phylloceras* sp. *?Acroteuthis* sp. trace fossil
A2015	*Shasticrioceras* sp. *Nucula gabbi* Stanton *?Modiolus* sp.
A2016	*Shasticrioceras hesperum* Anderson *Nucula storrsi* Stanton (2) *Inoceramus dunveganensis* Crickmay *Periplomya trinitensis* Anderson *Acroteuthis* sp. *"Acroteuthis"* sp.
A2017	*?Glycimeris* sp.
A2018	*Hoplocrioceras remondi* (Gabb) *Shasticrioceras poniente* Anderson (2) *Ancycloceras ajax* Anderson *Toxoceras stentor* (Anderson) *Acroteuthis aboriginalis* Anderson *Inoceramus colonicus* Anderson *Periplomya trinitensis* Anderson *Pholadomya distorta* Anderson *Pholadomya russelli* Anderson *Nucula storrsi* Stanton *Glycimeris ovatus* (Stanton) *Terebratella* sp. plant fragments fish scale
A2019-23	Unid.
A2024	*Acroteuthis* sp.
A2026-31	Unid.

Buck Mountain Formation (Cont'd)

Locality	Species
A4473	*Lytoceras* sp. *Shasticrioceras poniente* Anderson *?Phylloceras* sp. *Tropaeum percostatum* (Gabb)?
A4474	*Aulacoteuthis wyntoonianum* Anderson *Shasticrioceras poniente* Anderson *Shasticrioceras* sp. *Inoceramus colonicus* Anderson *Inoceramus* sp. *Pholadomya altumbonata* Anderson *Terebratella* cf. *T. whitmana* Anderson *Cycadophyte* sp.
A4475	*Inoceramus ovatoides* Anderson
A4476	*Shasticrioceras poniente* Anderson *Tropaeum percostatum* (Gabb)? *Inoceramus* sp. *Acroteuthis aboriginalis* Anderson? *?Acroteuthis* *Aulacoteuthis wyntoonianum* Anderson
A4477	*Shasticrioceras poniente* Anderson *Shasticrioceras* sp. *Acroteuthis aboriginalis* Anderson
A4478	*Shasticrioceras poniente* Anderson (2) *Tropaeum percostatum* (Gabb) *Inoceramus colonicus* Anderson *Acroteuthis impressa* (Gabb)? *Pholadomya* sp.
A4479	Unid.
A4480	*Tropaeum? percostatum* (Gabb)
A4481	*Cycadophyte* sp.
A4483	*Inoceramus colonicus* Anderson
A4560	*Shasticrioceras poniente* Anderson *?Aulacoteuthis* sp.
A4561	belemnite pelecypods
A4816	*Periplomya trinitensis* Anderson *Gyrodes expansa* Gabb *Goniomya vespera* (Anderson) *Linea multilineata* Stanton *"Trigonia"* sp. *Nautilus* sp. *Phylloceras* sp. *?Cucullaea* sp. (2)

Buck Mountain Formation (Cont'd)

Locality	Species
A4817	*Cyprimeria* cf. *C. patello*
A4818	*Pleuromya* cf. *P. harrisonensis* Crickmay *Shasticrioceras* cf. *S. hesperum* Anderson *Buchia* cf. *B. piochii* (Gabb) *?Cucullaea* sp.
A4822	*Periplomya trinitensis* Anderson *Inoceramus colonicus* Anderson *Inoceramus concentricus* Parkinson *Inoceramus* sp. *Anchura biangulata* Anderson *Pholadomya distorta* Anderson *Buchia* cf. *B. terabratuloides* (Lahusen) *Anomia* cf. *A. linensis* *Pseudoptera* sp. *Dentalium* sp. *?Shasticrioceras* sp. (2) Cephalopod
A5505	cycad
A5506	cycad (2) and other plant fossils, wood fragments
A5507	*Inoceramus ovatoides* Anderson *Inoceramus colonicus* Anderson *?Acteonina* pelecypod ribbed ammonite fragment
A5508	*Inoceramus ovatoides* Anderson *Inoceramus colonicus* Anderson *?Dentalium* sp. *Shasticrioceras* sp. hooked ammonite mollusk
A9665	*Inoceramus colonicus* Anderson *Inoceramus* sp.
B1370	*Corbula filosa* Stanton
B1374	*?Shasticrioceras* sp. [NOTE: Cole (1973) indicates this sample was collected from the Virginian Ridge Formation, but the genus indicates it probably came from the Buck Mountain Formation.]
B1375	*Inoceramus ovatus* Stanton *Inoceramus* cf. *I. colonicus* Anderson [NOTE: Cole (1973) indicates this came from the Virginian Ridge Formation but is likely mistaken. Probably from Buck Mountain Formation.]

Goat Creek Formation

No Fossils

Panther Creek Formation

Locality	Species
A4558	hamitid? smooth evolute ammonite large gastropod plant stem fragments *Anomia*-like clam [NOTE: This locality is probably Panther Creek Formation although Barksdale uses an earlier (tentative) name of "Harts Pass Beds".]
A5502	marine gastropods of turreted *Volutoderma* sp. types *Turitella* sp. pelecypod ostracod
A5503	*"Pleurotomaria"*-like gastropod plants
A9663	*Anchura biangulata* Anderson *"Trigonia"* sp. *?Macrocallista* sp. *?Actaeonella* sp. pelecypod
B1368	*Turbo festvus* Anderson *Trigonia* sp. *Turitella* sp. *?Corbula* sp. *Nerinea* sp. [NOTE: *Turbo festvus* occurs in the *Hertleinitis aquila* Zone of Murphy (1956) of late Hauterivian age. This locality may be in the Buck Fountain Formation as suggested by the zone, but lithologically it seems closer to Panther Creek Formation.]
B1371	*Toxoceras stentor* (Anderson) *Pedioceras* sp.

Harts Pass Formation

T. Matsumoto (Kyushu University, Japan) concurs with V. Standish Mallory's identifications from the Harts Pass Formation. A0954 was identified by D. L. Jones (1960).

Locality	Species
A0954	*Melchiorites* cf. *M. shastensis* Anderson *Puzosia* cf. *P. mayoriana* (d'Orbigny) or *P. sharpei* Spath *Puzosia* sp. *Turitella ?* sp. *Pinna* sp. *Hamites* sp. hamitid pelecypod ammonite
A1049	*Melchiorites* cf. *M. shastensis* Anderson *Hamites* sp.
A4472	*?Melchiorites* cf. *M. subquadratus* Anderson
A4562	Unid.
A4565	Unid.
A6222	*Douvilleiceras* cf. *D. mammillatum* (Schlotheim) *Hamites* cf. *H. attenuatus* (J. Sowerby) J. Sowerby *Hamites* sp. *Melchiorites* sp. *?Melchiorites* sp. *Hypophylloceras* sp. *Anomia* sp. *Dentalium* sp gastropods ?worms ammonite.
A6223	*Trigonia* sp.
A6224	*Buchia* sp. *Inoceramus* sp.? *Phylloceras* sp. *Cheloniceras* sp. mollusk plant organ plant stem
A6225	gastropods
A6226	*Nucula* sp.
A6227	*Anomia* sp.

Harts Pass Formation (Cont'd)

Locality	Species
A6228	*Gastroplites canadensis* Whiteaves
	Anomia sp.
	?Anomia sp.
	?Cheloniceras sp.
	?Mytilus sp.
	Douvilleiceras sp.
	Dumblea sp.
	Hamites cf. *H. attenuatus* J. Sowerby (2)
	Hamites sp.
	Hypophylloceras sp.
	?Hypophylloceras sp.
	Melchiorites sp.
	Pinna sp.
	?Buchia sp.
	?Pholadomya sp.
	?Inoceramus sp.
	?Glyptostrobus sp.
	?Glycimeris sp.
	Dentalium sp.
	mollusk
	pelecypod
	trace fossil
A6229	*Mytilus* sp.
	Pinna sp.
	Hamites sp. (big and straight)
	?Hamites sp.
	hamitids
	ammonite
	gastropod
A6230	*Hamites* cf. *H. attenuatus* J. Sowerby
	Melchiorites sp.
	?Hypophylloceras sp.
	Douvilleiceras sp.
	?Inoceramus sp.
	?Buchia sp.
	Pecten sp.
	?Phylloceras sp.
A6231	*Hamites* cf. *H. attenuatus* J. Sowerby
	trace fossils
A6232	*Phylloceras* sp.
A6233	ammonite (2)
A6234	*Hamites* cf. *H. attenuatus* J. Sowerby
A9972	*Hamites* sp.
B1367	Unid.
B1369	*Hamiticeras* cf. *H. pilsbryi* Anderson
	?Hamiticeras philadelphium Anderson

B1376 *?Puzosia* cf. *P. aldersonana* Anderson

B1510 *Hypophylloceras* cf. *H. onoensis* Anderson

Patterson Lake conglomerate

Samples from localities A0548 - A0565 are described in Maurer (1958). Maurer designated those localities WA-548 - WA-565. Trigonids identified with the assistance of D. L. Jones, USGS, written commun. (1960).

Locality	Species
A0548	*"Rhynchonella"* spp.
A0552	*Trigonia evansana* Meek *Astarte* sp.
A0553	*"Rhynchonella"* spp.
A0565	*Trigonia leana* Gabb *Trigonia troyiana* Gabb *Trigonia evansana* Meek *Polinices* cf. *P. shumardianus* Gabb *Turritella chicoensis* Gabb sensu lato *Astarte* sp. *"Rhynchonella"* spp.
A0591	*Megatrigonia condoni* (Packard) *Vaadio leana* (Gabb)? *Pterotrigonia oregona* (Packard)
A4819	*"Trigonia" troyiana* Gabb cf. *Yaadia leana* (Gabb)? (large and small specimens) *"Trigonia" evansana* *Nucula* sp. *Turritella* cf. *T. chicoensis* Gabb [NOTE: From conglomerate at the base of the Virginian Ridge Fm. as described by Barksdale (1975).]
A4820	*Turritella* cf. *T. chicoensis* Gabb *Dentalium* sp. [NOTE: In Patterson Lake conglomerate; see Maurer (1958).]
A4821	*Camptonectes platessa* White *Exogyra* sp. *Lucina* cf. *L. colusaensis* Stanton *Natica humilis* Gabb *Rhynchonella whitneyi* Gabb
A9662	*Brewericeras haydeni* (Gabb) [NOTE: Found as float in a hayfield. *Brewericeras haydeni* has been compared to a topotype of Gabb and is conspecific.]

Virginian Ridge Formation

In the collections of the Geology and Paleontology Division, Burke Washington State Museum. Trigonid identification with assistance of D. L. Jones (USGS, written commun., 1960).

Locality	Species
A0953	*Glycimeris* sp. pelecypods (molds and casts)
A0955	*Actaeonella packardi* Anderson
A4484	*Rhynchonella whitneyi* Gabb
A4485	*Actaeonella packardi* Anderson Unid. [NOTE: This is the classic *Actaeonella* locality at Slate Peak.]
A4564	Unid.
A4566	Unid.
A5501	*?Dentalium* sp. alveolus of belemnite cycad ?
A5504	unidentifiable plant [NOTE: May be Winthrop Sandstone.]
A8455	*Actaeonella packardi* Anderson *Turitella* cf. *T. hearni* Anderson
A9971	*Actaeonella packardi* Anderson *Turitella* sp.
B1372	*Actaeonella packardi* Anderson *Ditrupa cornu* Imlay
B1373	Unid.

Winthrop Sandstone

The following floral list was taken directly from Rau (1987). Localities were not specified in Rau's study.

ANGIOSPERMS:

Araliaephyllum westoni (Dawson) Bell
Araliopsoides cretacea (Newberry) Berry
Araliaephyllum rotundiloba (Newberry) Fritel
Ficus ovalifolia Berry
Sapindopsis belviderensis Berry
Sapindopsis sp.
Nelumbites sp.
Menispermites sp.
Menispermites sp. or *Nelumbium* sp.
Eucalyptophyllum sp.
palm fragment?
dicotyledon fragments

FERNS:

Cladophlebis virginiensis Fontaine
Cladophlebis impressa Bell
Cladophlebis cf. *septentrionalis* Hollick
Cladophlebis sp.
Gleichenites giesekianus (Heer) Seward
Gleichenites cf. *G. geiseckiana* Heer
Sagenopteris williamsii Newberry
Anemia cf. *A. supercretacea* Hollick

CONIFERS:

Widdringtonites reichii Heer
Pseudocyas steenstrupi Heer
Cyparissidium gracile Heer or *Sequoia fastigiata* Heer
Elatocladus sp. cf. *Cephalotaxopsis heterophylla* Hollick

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Map Sheet 1 of 3

GEOLOGIC MAP OF THE METHOW BASIN NORTH OF 49 N°

by
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1988

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