GEOLOGICAL SURVEY

OF CANADA

JURASSIC AND CRETACEOUS ROCKS ALONG HOPE-PRINCETON HIGHWAY AND LOOKOUT ROAD, MANNING PARK, BRITISH COLUMBIA

(SUPPLEMENT TO SECTION 10 OF 24TH INTERNATIONAL GEOLOGICAL CONGRESS GUIDEBOOK A03-C03)

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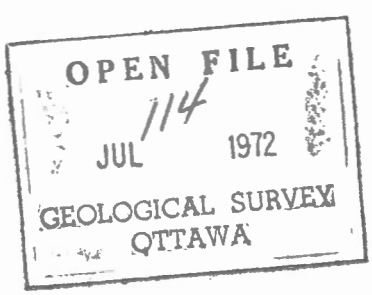

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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INTRODUCTION

The unmetamorphosed Jurassic and Cretaceous rocks of Manning Park area are restricted to a synclinorial, fault-bound structure on the eastern side of Cascade Fold Belt. This Mesozoic structure extends southeastward from Fraser River into the State of Washington and is limited by older metamorphic rocks on both sides (Coates, 1970, p. 149, Fig. 13-1). The Mesozoic rocks of Manning Park area are, perhaps, up to 30,000 feet thick and were recently subdivided in an ascending order into four groups (Coates, 1970, pp. 149-150; this paper, Fig. 1). Except for the almost exclusively non-marine Pasayten Group, they are exclusively to predominantly marine (Figs. 1,2).

GEOLOGICAL SUMMARY

Ladner Group

The early Middle (Bajocian) and Early Jurassic (Toarcian to Sinemurian) (Frebold 1967, p. 201; Frebold et al., 1969; Coates, 1970, p. 150, Fig. 13-2; this paper Figs. 1,2) Ladner Group is more than 6,000 feet thick; its base was not seen. The group outcrops in two northwest-trending belts (Coates, 1970 p. 152, Fig. 13-4) representing different facies.

The western facies consists of strongly indurated and commonly secondarily silicified typical flysch. This deep water (? mid-basin) facies appears to be restricted to the western outcrop belt and is believed to be more than 10,000 feet thick. It is exemplified by the Skagit Bluffs section (see pp. 12-14, Fig. 3) and is characterized by a regular and thin (commonly laminated), rhythmical interbedding of predominant argillaceous rocks with subordinated, mostly fine grained volcanic sandstones. Coarse grained arenites, grits and conglomerates occur rarely and are volumetrically insignificant, except near

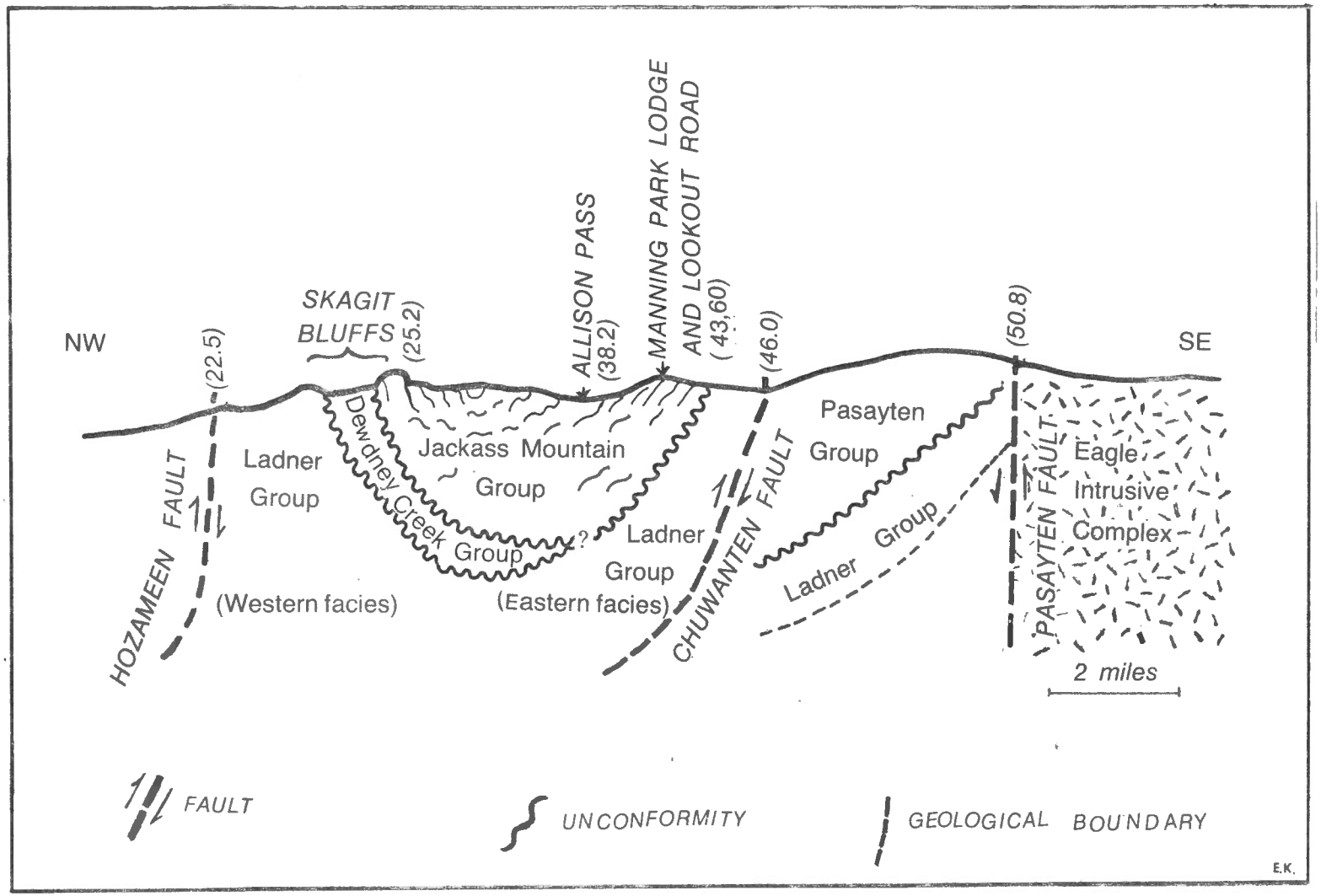

Figure 2. Diagrammatic structure section across eastern part of Cascade Fold Belt in Manning Park area (along Hope-Princeton highway). Largely based on Fig. 6 in McTaggart et al. (1968, p. 43) and Figs. 13-15 in Coates (1970, p. 153).

the top of the unit (Fig. 3). Intermediate to basic lavas and pyroclastics (mostly waterlain) occur but rarely as thin interbeds.

Abundance of groove and flute costs, graded bedding, and convolute bedding indicates deposition by turbidity currents. Indicators of current direction and facies pattern were interpreted as suggestive of an eastern source area (Coates, 1970, p. 150). There is no evidence of a western source area and the Ladner flysch trough must have extended westward into eastern Coast Mountains at least.

Another facies of Ladner Group is restricted to the eastern outcrop belt. It is exemplified by the Lookout Road sections (pp. 29-36, Figs. 8,9,). The apparent thickness of this eastern facies is in order of 6,000 feet according to Coates (in Frebold et al., 1969, p.1) but neither its top nor its base are exposed. Unlike the rocks of western facies, those of the eastern facies are, as a rule, neither strongly indurated nor silicifed. The argillaceous rocks are particularly friable and soft.

The upper 1,500 to ? 2,000 feet of the eastern facies are early Middle Jurassic (Bajocian) in age (Frebold et al., 1969, p. 32, 33). They consist predominantly of irregularly and indistinctly bedded to massive, poorly sorted, fine to coarse grained volcanic sandstones and volcanic pebble conglomerates irregularly alternating with thinly bedded to laminated fine grained arenaceous and argillaceous rocks. The latter rocks are volumetrically insignificant, except in the uppermost few hundred feet where they may be prevalent locally. Fossil wood is abundant throughout and the rocks are frequently coaly. The ratio of wood-bearing, coaly rocks gradually increases downward and the same is true of the volcanic conglomerates. Marine fossils (mostly ammonites) are largely restricted to argillaceous and fine grained arenaceous rocks.

Primary pyroclastics and lavas are rare to absent but arenites and rudites are commonly tuffaceous and may locally grade into waterlain pyroclastic rocks.

Slumped, "Wildflysch-like" intervals are common in the coarser grained arenites and rudites.

These lithological features, rapid lateral facies changes (westward thinning or shaling out of some arenaceous to rudaceous beds), and the common presence of ripple marks, channel scours, large scale current marks, and crossbedding suggest a fairly shallow to ? nonmarine origin for at least some coarser grained clastics in the upper beds of eastern facies. Others appear to be fluxoturbidites for reasons given below. Features suggestive of a turbidic redeposition (e.g., graded bedding, flute and groove casts, convolute bedding) are largely restricted to the thinly bedded to laminated fine grained arenites and argillites.

The insufficiently understood, about 4,000' thick middle and lower beds of the eastern facies appear to range from the late Toarcian or ? lower Bajocian (= Aalenian) to Sinemurian stage (Figs. 2, 9, description of Stop 6). They apparently consist predominantly of the same fine to coarse grained volcanic sandstones and pebble conglomerates as the upper beds but include several hundred feet thick units of andesitic pyroclastics and lavas at two ?or more levels (Fig. 5). These volcanics appear to be devoid of pillow structures.

Thinly bedded to laminated, argillaceous to fine grained arenaceous rocks appear to be restricted to thin, volumetrically insignificant interbeds, except at the visible base of the group. This may be, however, simulated in part by their recessive character resulting in the paucity of exposures.

Fossil wood, including twigs and sizeable tree trunks, is abundant at many levels, inclusive of some pyroclastic rocks. Coarser grained clastics are more commonly coaly than those in the upper beds; they include locally the apparently autochtonous small pods and thin lenticular interbeds of impure coal.

Marine fossils are largely restricted to argillaceous and fine grained arenaceous rocks and include a much greater ratio of shallow water benthonic types (pelecypod Weyla, rhynchonellid brachiopods, gastropods, colonial corals) than the upper beds. Therefore, much of the middle and lower beds, including their argillaceous types, is of a shallow water to nonmarine origin. These beds appear to include a considerably lesser ratio of redeposited deep water sediments (i.e. fluxoturbidites and true turbidites) than the upper beds.

Considered in toto, the eastern facies of Ladner Group resembles closely the so called "conglomeratic flysch" of Aalto and Dott, Jr. (1970). It appears to consist of an irregular interbedding of prevalent to considerable fluxoturbidites (Dzulynski and others, 1959, p. 1114) with minor true turbidites and considerable (above) to prevalent (below) shallow water marine to nonmarine deposits. Because of the general facies pattern of Ladner Group the flyschoid deposits of the eastern facies appear to be proximal trubidites and fluxoturbidites deposited by wesward directed, lateral (i.e. downslope) currents on the more or less steeply westward inclined eastern continental slope of Ladner Basin. This slope was apparently situated in a close proximity of either an elevated volcanic mainland or of a volcanic archipelago. The active volcanic nature of this eastern land (Coates, 1970, p. 151, Fig. 13-3) is indicated by the abundance of dacitic to andesitic detritus and clasts throughout the section and by the presence of considerable bodies of primary pyroclastics and lavas within it.

As already mentioned, the ratio of coarser grained fluxoturbidites and finer grained true turbidites appears to increase progressively upward, and that of the shallow water to nonmarine sediments appears to decrease progressively in the same direction. This suggests a gradual but probably pulsating deepening of the eastern part of Ladner Basin accompanied by a gradual eastward retreat of its eastern shoreline.

Dewdney Creek Group

The Late Jurassic (Oxfordian or ?Callovian to Portlandian s. str.) Dewdney Creek Group appears to overlie Ladner Group unconformably (Figs. 1,2). It is exemplified by the Skagit Bluffs section (pp. 15-18, Fig. 4). The group consists predominantly of massive to irregularly bedded but moderately to well sorted and rounded volcanic to polymictic, fine to coarse grained sandstones with considerable interbeds of more or less sandy siltstone in the western sections (Fig. 4). Considerable lenticular interbeds of massive to indistinctly bedded grit and pebble conglomerate are largely concentrated near the base of the unit and in its middle part (Figs. 3,4). These conglomerates are locally rich in granitic clasts which indicates that some granitic intrusions in the east were unroofed by late Jurassic time. Pods, thin layers and 10 to 100 feet lenticular interbeds of calcareous richly fossilferous sandstone or sandy coquina largely consisting of Buchia (= Aucella) are common in the upper part of the group. Any features suggestive of turbiditic redeposition are notably absent and all rocks appear to be shallow water to beach deposits.

The restriction of Dewdney Creek Group to the northwestern and southwestern parts of the area (Fig. 2) and the increase of conglomerates toward the east and northeast (Coates in McTaggart et al., 1968, p. 43, Fig. 6; Coates, 1970, p. 150) indicates that these marine rocks were deposited along the eastern margin of Tyaughton Trough (Jeletzky, 1970, p. 223) and were derived from an extensive north or northwest-trending landmass occupying the northeastern part of Manning Park area.

Jackass Mountain Group

The mid- to late Lower Cretaceous (late Hauterivian to late Albian) Jackass Mountain Group overlaps unconformably Ladner and Dewdney Creek groups (Figs. 1,2). This up to 14,000 feet thick group is exemplified by sections at the eastern end of

Skagit Bluffs (see Stop 2) and on Lookout Road (see Stops 3 and 4). Jackass Mountain Group underlies most of Manning Park area (Coates, 1970, p. 150, Fig. 13-4) and exhibits a facies pattern similar to that of Ladner Group (Jeletzky, 1970, p. 214- 219, 222-223, Fig. 1).

The ubiquitous, arenaceous basal unit of Jackass Mountain Group (i.e. Lower greywacke member) is a diachronic shallow water to nonmarine deposit which includes considerably older (Hauterivian) marine beds in the northwestern and southern parts of the area than farther east and northeast and is partly nonmarine in the eastern part (Fig. 1). It records a gradual eastward to northeastward transgression of the shallow Hauterivian to mid-Barremian sea over the bevelled surface of Ladner and Dewdney Creek groups following a prolonged late Tithonian and early Neocomian period of uplift and erosion (Jeletzky 1970, p. 222; Coates, 1970, p. 151, this report Figs. 1, 2).

The younger beds of the Barremian to Aptian greywacke unit of Jackass Mountain Group are restricted to the eastern part of the area (Fig. 1) and represent its eastern facies. These beds are of neritic, littoral and beach origin because of the abundance of fossil wood, irregular bedding, common presence of crossbedding and ripple marks. and the presence of coquina layers rich in shallow water pelecypods and gastropods.

The equivalent, almost exclusively argillitic rocks of the western part of the area (i.e. the lower and middle parts of the Barremian to Albian shale unit; see Fig. 1) represent the western or "offshore" facies which was apparently deposited in the lower neritic environment on a gently inclined shelf of Jackass Mountain basin and does not seem to include any turbidites. These irregularly and indistinctly bedded, mostly sandy, moderately to scantily fossiliferous argillitic rocks are overlain conformably and apparently gradationally by flyschoid, thinly bedded to laminated, early lower Albian shales and siltstones devoid of shallow water benthonic fauna. The appearance of these commonly graded and sole marked turbidites indicates a rapid deepening of

Jackass Mountain basin at the onset of Albian time. This deepening appears to be coeval with a major eastward transgression as the deep water argillaceous early lower Albian flyschoids overlap the marginal Barremian-Aptian greywacke unit in the Manning Park Lodge-Windy Joe Mountain area (Fig. 1 and in description of Stop 3).

The deposition of argillaceous early lower Albian deep water turbidites was followed by a widespread deposition of Lower Albian conglomerate unit. For reasons discussed in description of Stop 3 this marine conglomerate is a deep water turbidite. It must have been transported from the narrow eastern shelf zone of the early Lower Albian Jackass Mountain basin by powerful lateral turbidity currents and redeposited as a chain of mostly overlapping deep sea fans in the lower parts of submarine canyons and valleys of the continental slope and/or at its base.

The Lower Albian conglomerate unit was derived from a northeastern source area. It is from 1,000 feet + to ? 2,000 feet thick in the easternmost outcrops between Allison Pass and Windy Joe Mountain (see Fig. 1 and pp. 20-24 of the Itinerary). Northwest of Allison Pass the conglomerate thins out gradually first to several hundred feet between the headwaters of Skagit River and Skaist River crossing and then to only 20 to 100 feet in the northwesternmost outcrops halfway between Skaist River and Skagit Bluffs. West to west-southwest of the Allison Pass-Windy Joe Mountain outcrops the conglomerate thins out to between 500 and 250 feet and apparently splits up into a series of disconnected lenticular bodies (?disconnected front lobes of deep sea fans) in the Gibson Pass-Poland Lake outcrop belt.

The widespread deposition of Lower Albian conglomerate unit indicates the occurrence of strong uplifts of the eastern mainland flanking the Jackass

Mountain Basin. Judging by its deep sea nature, however, these uplifts were not accompanied by an appreciable shallowing of the basin proper.

The several thousand feet thick Variegated Albian rocks appear to overlie the Lower Albian conglomerate unit conformably and to replace it laterally in the southernmost and westernmost parts of the area (Fig. 1). These poorly known late lower (Brewericeras hulenense zone) to upper (Mortoniceras (s. lato) sp. indet. zone) Albian marine rocks appear to be largely proximal or mid-basin turbidites and fluxoturbidites because of their predominantly flyschoid lithology, common presence of graded bedding and sole markings, and an apparent absence of shallow water benthonic fauna.

So far as known, the facies pattern of Variegated Albian rocks duplicates that of the older parts of Jackass Mountain Group. About 300 feet of shallow water arenites and siltstones locally replete with Pterotrigonia ex aff. columbiana (Packard), P. ex aff. oregana (Packard), other thick shelled pelecypods, and actaeoninid and naticid gastropods (e.g. GSC loc. 74799, 74801) form the visible top of Variegated clastic unit in northeastern part of the area (e.g. north of Allison Pass). Farther southwest (e.g. in headwaters of Memaloose Creek near Poland Lake, GSC loc. 14927) the contemporary or younger late Albian rocks forming the top part of the unit are represented by Mortoniceras (s. lato) sp. -bearing, flyschoid argillites. Therefore, contrary to Coates (1966, p. 56; 1970, p. 151, Fig. 13-3) opinion, all of the Jackass Mountain Group of Manning Park area was deposited on the eastern limb of Tyaughton Trough and derived exclusively from an eastern or northeastern landmass (Figs. 1, 2). The present day synclinorial structure of the Manning Park Mesozoic Belt and its separation from Harrison Lake Mesozoic Belt by the structurally positive belt of Hozameen metamorphics is attributable to the post-Lower Cretaceous inversion of Tyaughton Trough (Jeletzky, 1970, p. 223 and in the discussion of Pasayten Group).

Pasayten Group

The at least 10,000 feet thick (most recent estimate) Pasayten Group is faulted against Ladner Group in the eastern part of Manning Park Mesozoic Belt (Coates, 1970, p. 151, Fig. 13-4). It is exemplified by the section at the upper end of Lookout Road (see Fig. 10 and Stop 7).

Unlike Jackass Mountain Group, the Pasayten Group consists mainly of arkose and subarkose with minor conglomerate and siltstone. It is subdivisible into a lower, at least 8,000 feet thick unit consisting of arkose and subarkose with some partly coaly, nonmarine to marine siltstone. This unit is overlain by middle unit consisting of about 1,000 feet of nonmarine, poorly sorted and lithologically variegated red-coloured clastics. These predominantly arenaceous to argillitic rocks contain much volcanic material. The middle "red beds" are overlain by the conglomeratic upper unit consisting of more than 1,000 feet of grey nonmarine (fluviatile), lithologically variegated (from greywacke to arkose), mostly medium to coarse grained and gritty to pebbly arenites commonly rich in pods, stringers and 1 inch to 5 feet lenticular interbeds of grit and pebble conglomerate. Considerable, mostly lenticular beds of pebble conglomerate apparently devoid of granitic pebbles and minor interbeds of sandy siltstone occur in the unit. All of the "Neocomian (?)" nonmarine beds of Coates (1970, p. 150) are included in this unit on lithological and stratigraphical grounds.

Albian marine fossils are restricted to the middle part of the lower unit (Coates, 1967, p. 57). According to Coates (1970, p. 151), a significant lithological change occurs at the base of the middle "red beds" which: "record a gradual change in provenance from an easterly granitic source to a westerly source composed mainly of volcanic and sedimentary rocks. Some pebbles in conglomerates from the upper unit appear to be derived from the Hozameen, Ladner and

Jackass Mountain Group."

As already mentioned, the Jackass Mountain Group situated to the west of Pasayten Group includes the reliably dated (ammonites) latest Lower Cretaceous (late Albian) high marine rocks evidently derived from an easterly source. The gradual change of the provenance of the Pasayten Group sediments noted by Coates (1970, p.151) must, therefore, have occurred at some post-upper Albian time. The Lower-Upper Cretaceous boundary is accordingly placed at the base of red beds and an early Upper Cretaceous (Cenomanian ? and younger) age is assigned to the middle and upper units of the Pasayten Group. This conclusion is, furthermore, supported by the syntectonic (molasse-like) lithology of the upper unit of the group (Fig. 10 and discussion of Stop 7) suggestive of its deposition by fast moving streams after a general emergence of the Cascade Fold Belt.

The Pasayten depositional basin was one of several isolated nonmarine troughs which existed in southwestern British Columbia following the regional retreat of the Cretaceous (? latest upper Albian) sea from and the tectonic uplift of the Tyaughton Trough.

ITINERARY

Leave Manning Park Lodge and drive northwest on Princeton-Hope highway to Skagit Bluffs situated approximately 24.2 to 26.0 miles east of Hope on the north side of Skagit River canyon. See pp. 16-20 of Itinerary for details of geology along the route.

SKAGIT BLUFFS

Stop 1

Leave buses at point about 5/8 of a mile east of western end of Skagit Bluffs.

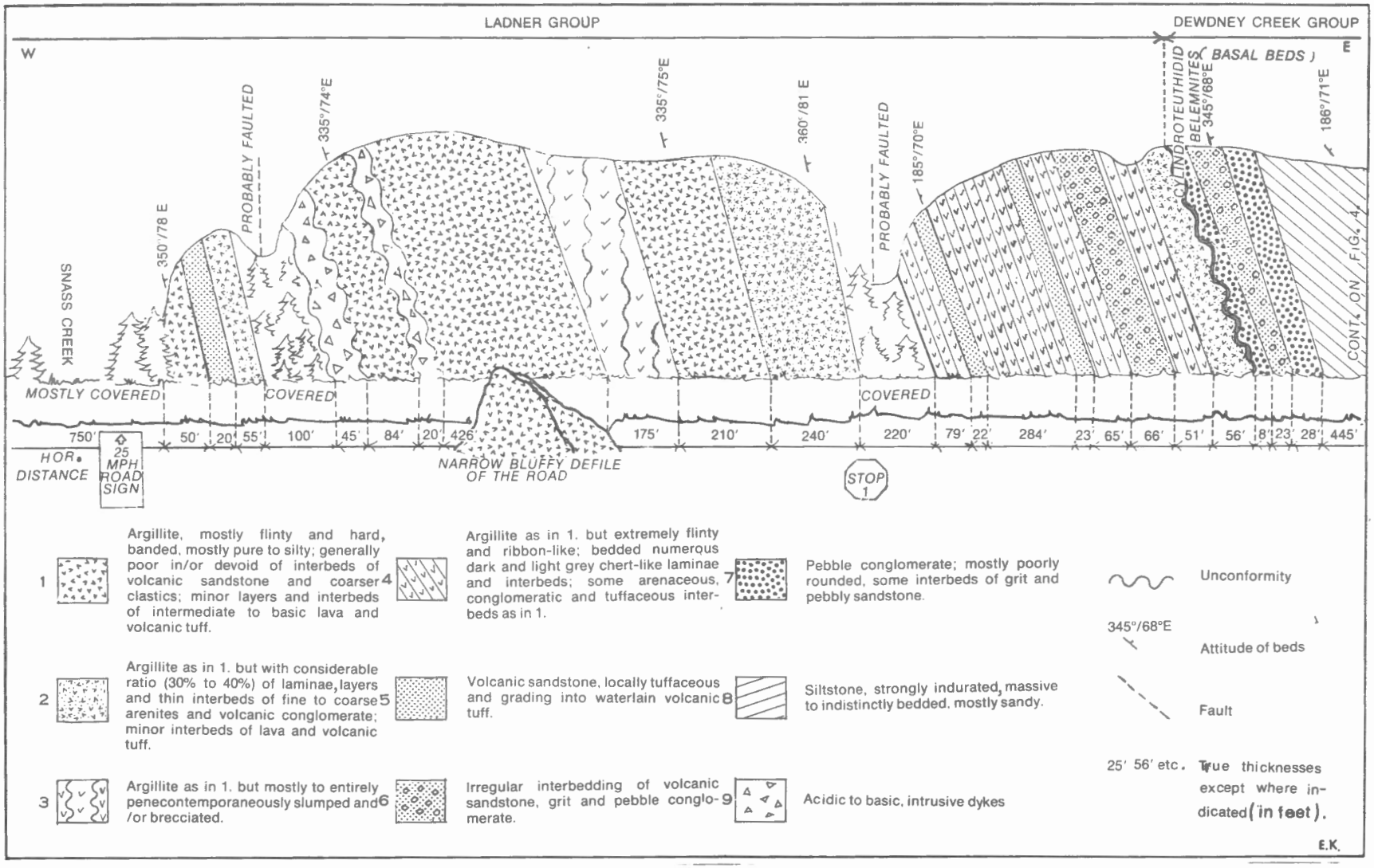

Figure 3. Section of the upper part of Ladner Group in bluffy roadcuts on the north side of Hope-Princeton highway at Skagit Bluffs.

The about 7/8 of a mile long western part of Skagit Bluffs exposes the upper 2,300 feet of predominantly argillaceous flysch of the western facies of Ladner Group (Fig. 3). Most of these rhythmically alternating, thinly bedded argillites and fine grained, volcanic sandstones are true mid-basin trubidites as they commonly exhibit graded bedding, convolute bedding and sole markings. The interbeds of gritty and pebbly greywacke and pebble conglomerate could be fluxoturbidites derived from an eastern source. Some thin interbeds of light coloured, ? siliceous volcanic tuff and intermediate to basic lava occur locally. All stratigraphical tops are to the east. Except for Coates (1950,p.150; see p. 3) work, no study was made yet of directional sole markings.

No fossils of any kind have been found in this section of Ladner Group. Bajocian and late Toarcian fossils occur, however, in the adjacent largely equivalent, Divide section south of Skagit River (Frebold et al., 1969, p. 9-11, Fig. 3). All lithological types are hard and siliceous. Cherty-textured interbeds occur locally but true cherts are rare according to Coates (in Frebold et al., 1969, p.6).

The strong induration and silicification of all lithological types of the western facies is in contrast with the eastern facies where these phenomena are characteristically absent. This is probably a secondary phenomenon attributable to the influence of nearby plutons which are restricted to the western part of the area. The thermal alteration and mineralization of the western facies of Ladner Group is most pronounced near the west end of Skagit Bluffs. Axinite is common there, and tourmaline, adularia, prehnite, stilbite and laumontite are also found according to Coates (in McTaggart et al., 1968, p. 43).

Walk on foot for about 1/4 mile east to well exposed, disconformable and apparently unconformable contact of Ladner and Dewdney Creek groups.

The lithology of the belemnite-bearing, shallow water to ? beach deposited basal conglomerates and grits of Dewdney Creek Group contrasts with that of the mid-basin turbidites and ? fluxoturbidites of the underlying upper part of Ladner Group. This initial phase of the early Upper Jurassic transgression was preceded by a long interval of uplift and erosion (the regional Bathonian interval; see Figs. 1, 2).

Board buses and travel ¾ of a mile east to the point closely east of the eastern end of Skagit Bluffs.

The about ¾ mile long eastern part of Skagit Bluffs east of Ladner-Dewdney Creek contact (Fig. 4) exposes a complete but structurally complex, about 1,025 feet thick section of Dewdney Creek Group and that of the Basal greywacke member of Jackass Mountain Group.

Stop 2

The about 700 feet thick unit of strongly indurated black to bluish grey, argillaceous rocks exposed at the base of a forested slope at left for some 800 feet eastward of the eastern end of Skagit Bluffs (Fig. 4) only represents the lower part of the at least 2,000 feet thick Barremian to Albian shale unit. (Jeletzky 1970, p. 221, Fig. 1; this report Fig. 1). Its synclinally bent middle and upper beds underlie densely wooded higher slopes of the northern side of Skagit River Valley in the interval 26.0 to 28.6 miles east of Hope (see below). These mostly massive to indistinctly bedded, sparcely fossiliferous argillaceous rocks lack any signs of turbiditic resedimentation and contain some deep neritic bentonic fossils. They were apparently deposited by superficial forces in a moderately deep, quiet marine environment some distance from the eastern source area.

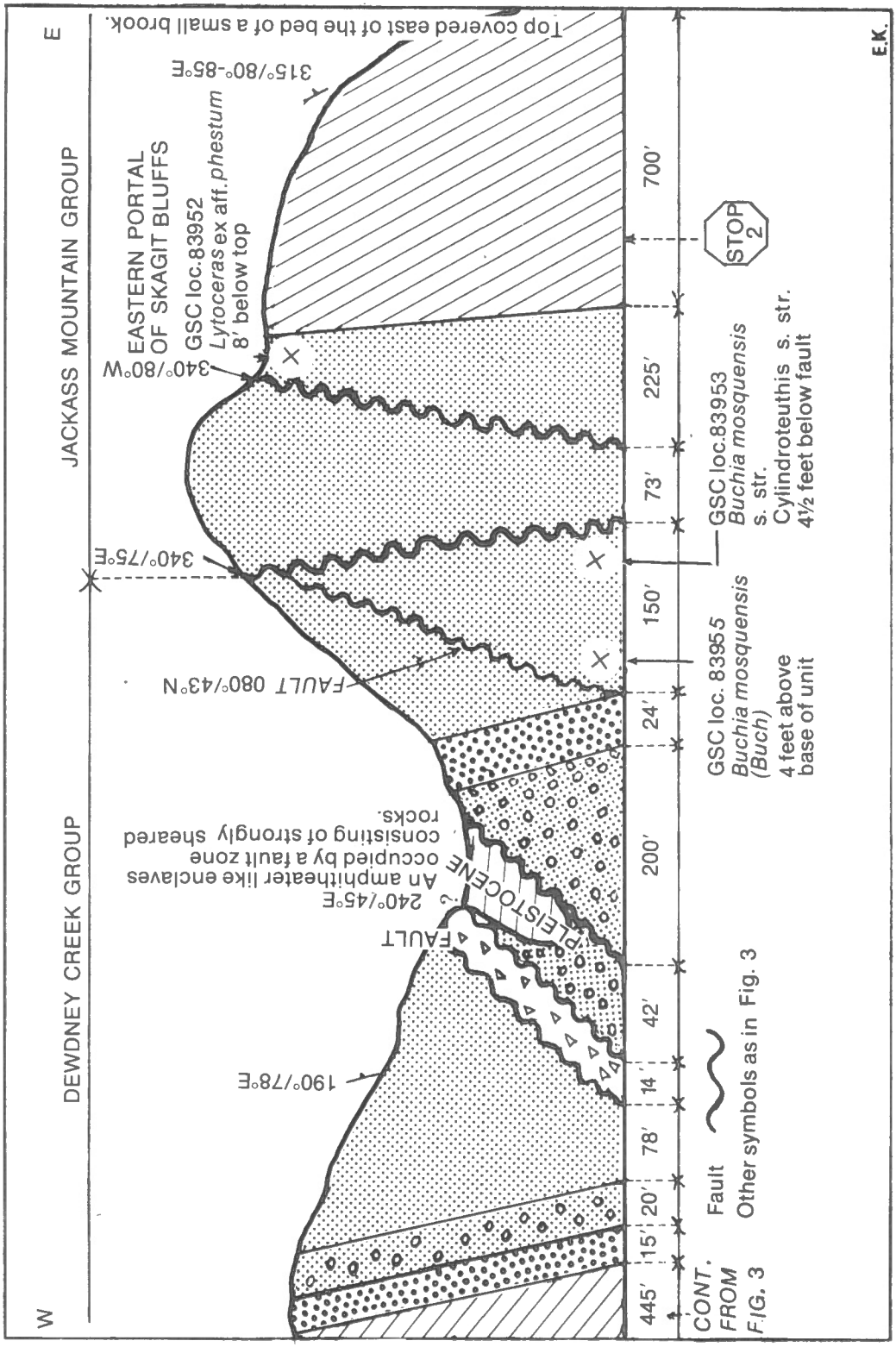

Figure 4. Section of Dewdney Creek Group and the Lower part of Jackass Mountain Group in bluffy roadcut on the northern side of Hope-Princeton highway. The section extends over the eastern part of Skagit Bluffs and is continuous with that of Figure 3.

Walk on foot westward to inspect exposures of basal Jackass Mountain and Dewdney Creek groups.

The strongly indurated, fine grained, neritic sandstones of the Lower greywacke unit are lithologically indistinguishable from underlying sandstones of the upper Dewdney Creek Group. The presence of a prolonged hiatus and unconformity between these groups (Figs. 1, 2) is only evident on palaeontological and regional-structural grounds. Considered alone, the total absence of late Tithonian to mid-Hauterivian faunas and the presence of the mid-Barremian Eulytoceras ex aff. E.phestum (Matheron) fauna (GSC loc. 83952) closely above mid-Kimmeridgian to early Portlandian Buchia mosquensis (Buch) s. lato fauna (GSC loc. 83953 and 83954) in Skagit Bluffs section could be explained by faulting (Fig. 4).

Buchia-bearing greywacke is underlain conformably by about 350 feet of mostly coarse grained, gritty and pebbly sandstone, grit and mostly fine, moderately to well rounded pebble conglomerate locally rich in granitic pebbles. These irregularly interbedded apparently unfossiliferous clastics appear to be beach deposits.

About 445 feet of dark to brown grey, rust-weathering, strongly indurated siltstones intervene between the coarser clastics and basal conglomerates of Dewdney Creek Group (Fig. 4). These unfossiliferous siltstones appear to lack the regular thin rhythmical bedding and other turbiditic features of Ladner Group argillites and were apparently deposited by superficial forces in a moderately deep and quiet marine environment.

FROM SKAGIT BLUFFS TO LOOKOUT ROAD

Leave Skagit Bluffs and drive southeast to the junction with the Lookout Road. The intervening about 17 miles long stretch of Hope-Princeton highway and

the surrounding slopes are underlain by structurally complex rocks of Jackass Mountain Group.

26.0 to 27.3 miles (from Hope). The roadcuts and the walls of Skagit River canyon expose siltstones and shales of the lower (i.e. Barremian) part of Barremian to Albian unit previously seen at the eastern end of Skagit Buffs (Stop 2; see Fig. 4). The best section is on the left 400 feet downstream of Skagit River campsite.

27.3. Cross Skagit River at Skagit River Campsite. Exposures of the same argillites in river's banks. The road moves steadily down-section.

28.6. Cross Skaist River. Dip slopes of argillite and sandstone on left represent transition beds between Barremian to Albian shale unit and the underlying lower greywacke member.

28.6 to 29.5. Road begins to move upsection recrossing the whole thickness of Barremian to Albian shale unit.

29.5. Exposure of the still thin Lower Albian conglomerate unit on left. Skagit River has cut a narrow canyon through this conglomerate and associated volcanic sandstone on the right. Road continues to move upsection.

29.8 to 32.7. Roadcuts on left are in flyschoid, lithologically variegated, Albian clastics overlying the Lower Albian conglomerate unit (see Fig. 1). The argillite and sandstone section is strongly faulted. Road begins to move down-section again.

32.7. Fine exposures of the same argillite-sandstone section of the Variegated Albian clastics. Excellent graded bedding in some of the sandstones indicates the turbidite nature of these rocks. Faulted exposures of marine Lower Albian conglomerate unit in river's bank on the right.

32.7 to 35.0 Road climbs toward the western side of Allison Pass through a burned out area underlain by strongly folded and faulted rocks of

Jackass Mountain Group. Roadcuts on both sides and the banks of Skagit River on the right expose argillite, conglomerate and sandstone representing various units previously seen.

The bluffy, high ridge on the upper slopes on left is underlain by the now several hundred feed thick marine Lower Albian conglomerate unit dipping away from observer. This unit appears to be a turbidite. Gentler lower slopes on left are underlain by argillaceous partly turbiditic rocks of the Barremian to Albian shale unit underlying the conglomerate.

35.0 to 35.8. Marine sandy siltstone and silty volcanic sandstone exposed in roadcuts on left represent the interfingering of the upper Barremian to Albian shale unit (an offshore facies) with the Upper greywacke member (a shallow water facies) depicted in middle graph of Fig. 1. The overlying Lower Albian conglomerate unit gradually approaches the valley's bottom until its base plunges beneath the bed of Skagit River 400 feet upstream (i.e. east) of the spot where the river crosses the left side of road in a culvert.

35.8 to 36.1. Sharp road bend offers excellent exposures of Lower Albian conglomerate unit in roadcuts on the right and river's bed on the left.

36.6 Lower Albian conglomerate unit disappears from outcrops being cut off by a strong cross fault.

36.6 to 42.6. On both sides of Allison Pass the road follows the valley underlain by synclinally bent and faulted variegated Albian clastics overlying the Lower Albian conglomerate unit (Fig. 1). Exposures are mostly poor and the bedrock is locally covered by thick Pleistocene gravels.

42.6 to 43.6. The now at least 1,000 feet thick Lower Albian conglomerate unit reappears in steep, densely wooded lower slopes on the left and continues to outcrop there to the entrance to Lookout Road opposite Manning Park Lodge. Poor outcrops of the variegated Albian rocks continue in the wooded slopes beyond

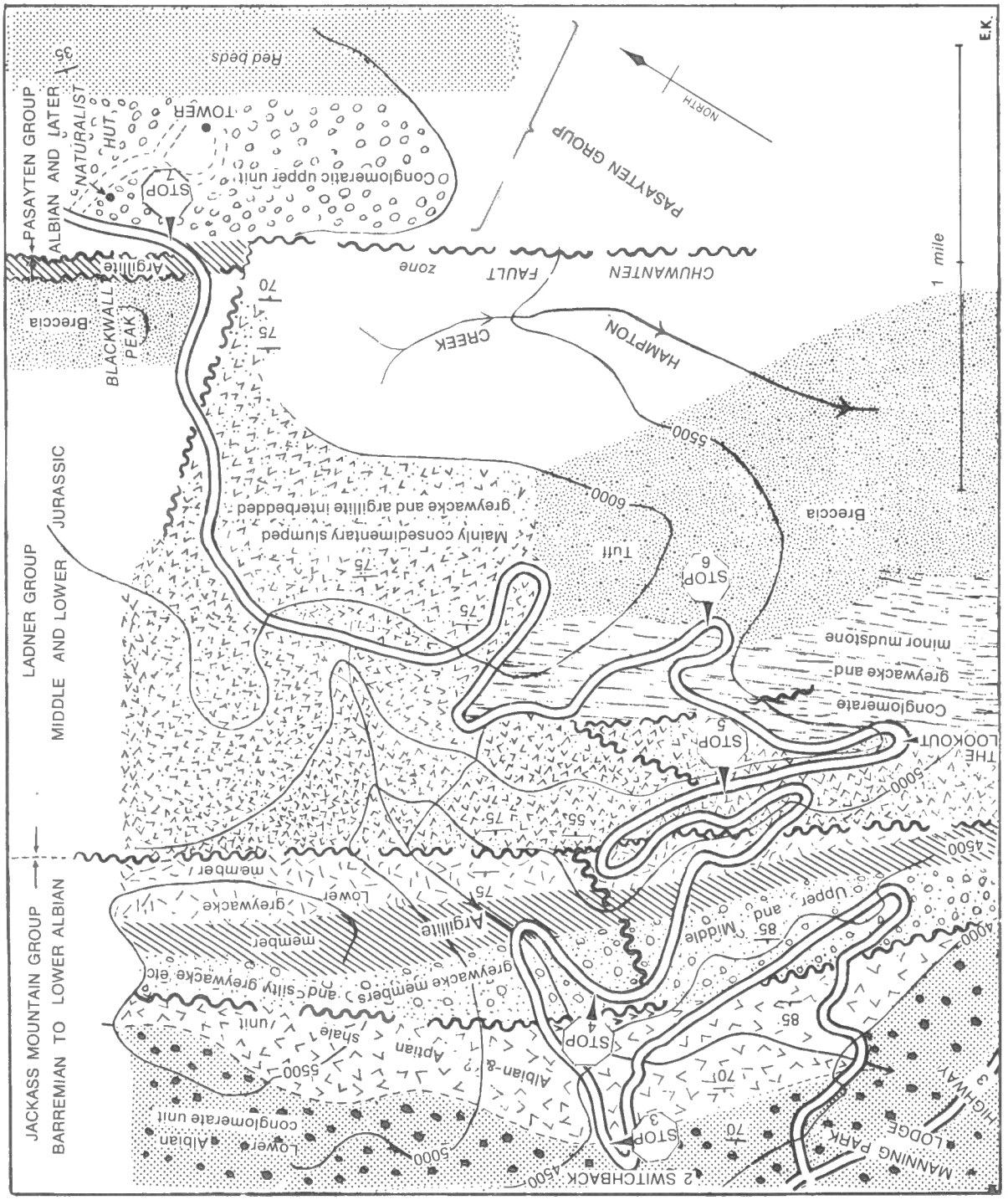

Figure 5. Geological sketch map of Mesozoic rocks exposed on Lookout Road north of Manning Park Lodge. Partly based on geological sketch map in McTaggart et al., (1968, p. 45, Fig. 7).

the bed of Similkameen River on the right.

43.6. Turn left (i.e. north) into Lookout Road at the entrance to Manning Park Lodge (see Fig. 5.)

LOOKOUT ROAD

The Lower Albian conglomerate unit continues to outcrop in roadcuts for about 3/8 of a mile upslope. Thereafter the gentle slopes are underlain by the Lower Albian and ?Aptian shale unit for about ¼ of a mile. These rocks are faulted (fault's trace is covered) against the Upper greywacke member at the point about 1/5 of a mile before 1st switchback (Fig. 5).

Scattered outcrops of closely jointed and orange-weathered (?hydrothermally altered) rocks of Upper greywacke member occur on the right for about 3/8 of a mile above 1st switchback (Fig. 5). Then scattered outcrops of dark grey, thinly bedded argillitic rocks of Lower Albian and ?Aptian shale unit extend for about 5/8 of a mile on right to the 2nd switchback. These outcrops are on southwestern side of above mentioned fault (Fig. 5).

Stop 3

Leave buses and walk to northwestern bluffy side of 2nd switchback which exposes the basal 200 feet of marine, Lower Albian conglomerate unit and its abrupt but perfectly even contact with the underlying Albian and ? Aptian shale unit (Fig. 6). Granitic clasts predominate in the conglomerate but various volcanic and sedimentary (especially chert) pebbles are common.

The unit exhibits a cyclical alternation of lithologies beginning with a tightly packed, coarse pebble to boulder conglomerate with well to moderately rounded clasts in a scarce sandy to fine pebbly matrix. This conglomerate is restricted to basal ½ to 2 feet of each of cyclically repeating heavy beds or 30 to 50 feet thick members. It grades upward into much more sparcely pebbly

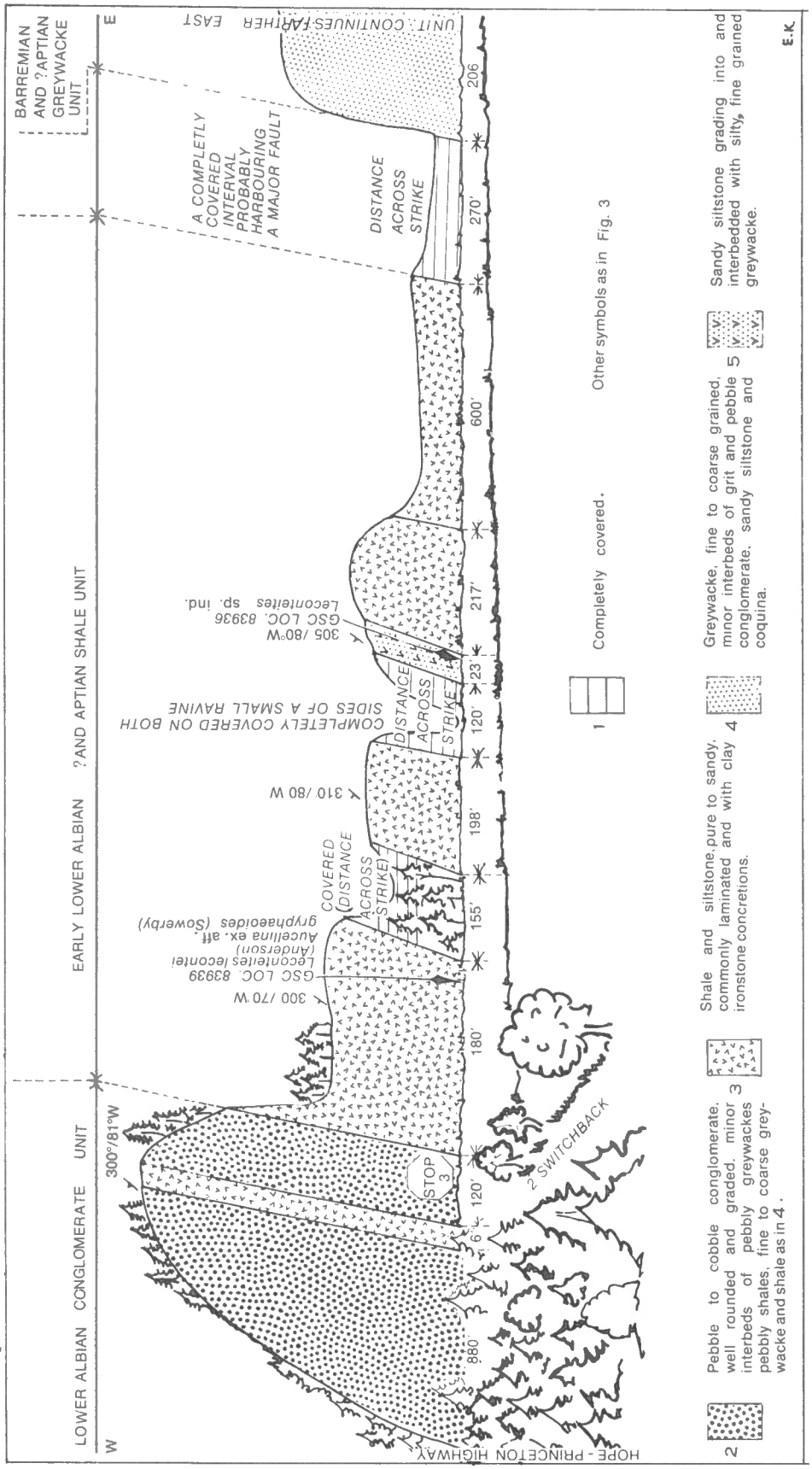

Figure 6. Section of Jackass Mountain Group in the roadcut on northwestern side of Lookout Road above 2nd switchback from its lower end. View due NW.

and finer conglomerate rich in mostly fine grained greywacke matrix. This conglomerate grades in turn into a still more sparcely and finer pebbly conglomerate rich in a mixed mudstone-fine greywacke or mudstone matrix and the latter, finally, into a pebbly to pure mudstone. Then the cycle is repeated. The basal contact of each cycle tends to be abrupt but even.

The graded bedding, rare presence of ammonites (Jeletzky, 1970, p. 219) and thin shelled deep water pelecypods (? Aucellina sp.) and a complete absence of shallow water fossils indicates that the conglomerate is a deep water turbidite derived from a narrow shelf zone. See pp. 8-9 of the Introduction for further details.

The flyschoid thinly bedded to laminated argillaceous rocks of the underlying Albian and ? Aptian shale unit exposed beneath the conglomerate, exhibit graded bedding and various sole markings locally. They appear to be turbidites, in part at least.

Walk on foot up the road to a fossiliferous bed of Albian to ? Aptian shale unit situated 140 feet stratigraphically below the contact with the Lower Albian conglomerate unit on the left side of the road. This 3 to 5' thick bed (GSC loc. 83993) contains fairly rare Brewericeras (Leconteites) lecontei (Anderson) and Aucellina ex aff. A. gryphaeoides (Sowerby). This apparently, deep water fauna occurs at several levels in this argillaceous flysch.

Board buses and resume the trip.

Scattered outcrops of argillaceous rocks of the Albian ? and Aptian shale division continue on the left for about 3/8 of a mile up from 2nd switchback. They are followed by a 270 feet wide covered interval harbouring the northwestern continuation of previously crossed fault (Fig. 5).

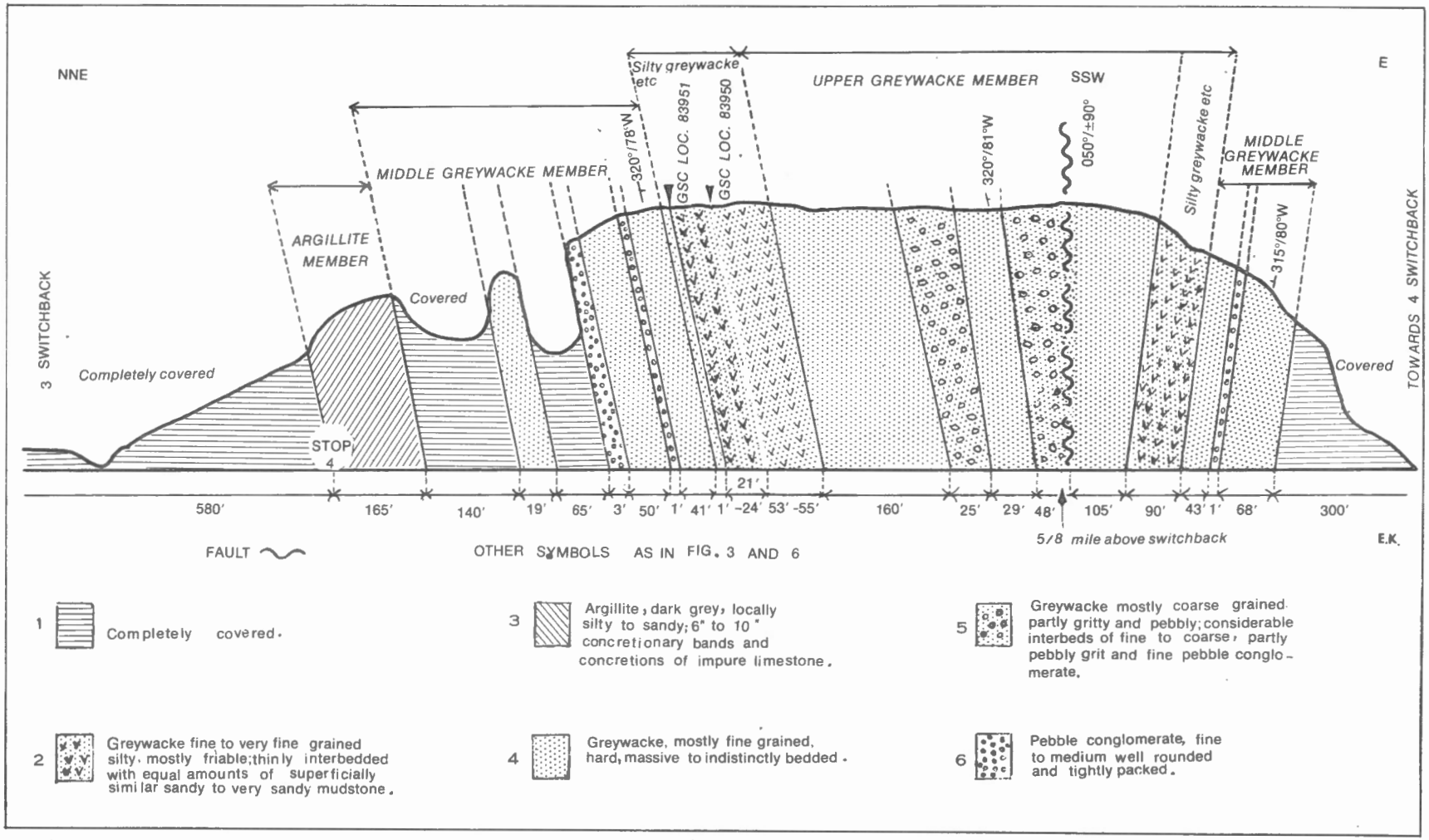

Figure 7. Section of the Barremian to Aptian greywacke unit of Jackass Mountain Group in the lower northern part of the 4th stretch of the Lookout Road. View generally east. The section was measured around a hooflike bend of the road (see Fig. 5) which results in the re-appearance of the same rock units in a reversed order (and with apparently reversed dips) on both sides of the fault.

Buffy exposures of the Upper greywacke, Silty greywacke etv., and Middle greywacke members on the left occupy most of the remaining ¼ mile long interval to the 3rd switchback. This section nearly duplicates the section presented in Fig. 7.

The almost covered densely wooded interval around 3rd switchback is underlain by the Argillite member. Then the younger beds of Barremian to Aptian greywacke unit reappear in a reverse (i.e. upward) order on the left within 4th stretch of Lookout Road (Figs. 5, 7).

Stop 4

Leave buses at point about 200 yards above 3rd switchback and proceed on foot for about ¼ of a mile up the road to inspect the section presented in Fig. 7.

The roadcuts of the fourth stretch of the Lookout Road expose the best section of the Barremian to Aptian greywacke unit (Jeletzky, 1970, pp. 216-218, Fig. 1) known. This section only lacks the at least 130 feet thick uppermost (Aptian) beds, lower part of Argillite member and all of Lower greywacke member. The latter two units are, however, well exposed farther up the road in another section (see below).

Only the upper 165 feet of Argillite member are exposed (Fig. 7). This dark grey, brown-weathering, locally silty to sandy argillite with 6 to 10-inch thick concretionary bands and concretions of impure limestone is a tongue of the argillaceous offshore facies (i.e. of the late Barremian to lower Albian shale unit of the western part of the area; see Figs. 1,4 and in description of Stop 2). Fossils are scarce but the presence of Ancyloceras (? Lythancylus) n.sp. (GSC Loc. 62321) in combination with the stratigraphic position of the

member suggests its late Barremian age.

Middle greywacke member overlies the Argillite member conformably. It is about 320 feet thick but exposures are poor in the lower 225 feet (Fig. 7). The member consits of ash-grey, brownish grey weathering, mostly fine grained and massive-looking greywacke with minor interbeds of dark grey mudstone and well rounded, fine to medium pebble conglomerate rich in granitic pebbles. Only very rare, nondiagnostic marine pelecypods have been seen in these woodbearing littoral to beach deposits.

Silty greywacke-sandy mudstone member is about 78 feet thick (Fig. 7). It consists of mostly thin but irregular interbedding of brown grey to dark brown-weathering, fine to very fine grained, silty, friable greywacke with somewhat darker coloured sandy to very sandy mudstone containing some orange-weathering inclusions of ferruginous mudstone. Some coarse grained interbeds of gritty and fine pebbly greywacke. Both contacts are conformable but may be abrupt. More or less rare late Barremian ammonites, belemnites, pelecypods and irregular echinoids occur at most levels. The basal 4-5 feet (GSC loc. 83951) and the level 53 feet below top (GSC loc. 83950) are more fossiliferous than the rest of the member. The member is mostly rich in small fragments of fossil wood and comminuted plant fragments. A lower neritic environment is suggested by absence of coquina layers, rarity of gritty and pebbly interbeds and particles, and the relative rarity of thick shelled pelecypods such as Yaadia, Quoiecchia, and Pholadomya.

Upper greywacke member is about 262 feet thick. Light to medium grey or green grey, brown-weathering, mostly fine grained, hard, massive to indistinctly bedded greywacke predominates, except in topmost 48 feet and in the interval 77 to 102 feet below top. These two intervals consist of mostly coarse grained, partly gritty and pebbly greywacke and grit with considerable interbeds of fine pebble conglomerate. These intensively crossbedded and ripple marked intervals

appear to be largely beach deposits. They are mostly devoid of marine fossils and rich in wood fragments.

The lower 160 feet of the member consist of predominantly fine grained, massive-looking greywacke poor in or apparently devoid of marine fossils, except in the basal 13 to 14 feet. These basal beds are represented by thinly but irregularly bedded, calcareous greywacke with some interbeds and pods of gritty and fine pebbly coquina (GSC loc. 83948) rich in the same apparently late Barremian ammonites, etc. as in the underlying Silty greywacke, etc, member. These coquinoid interbeds are rich in fossil wood, including sizable tree trunks, and are locally coaly. A neritic marine environment is indicated for these basal beds at least. The rest appears to be littoral to beach deposits.

Another interbed of fine grained, thinly but irregularly bedded, calcareous, marine greywacke occurs 77 to 48 feet (approx.) below top of the member. It contains the same apparently late Barremian fauna as the underlying beds (Jeletzky, 1970, p. 218, Fig. 1) largely concentrated in two 1 to 1½ feet thick coquina beds at the top (GSC loc. 83946) and the base (GSC loc. 83947) of the interval. A littoral to neritic environment is indicated by abundant ripple marks, presence of coquina layers, abundance of wood fragments, common occurrence of thick shelled pelecypods (Yaadia), and the commonly fragmentary state of uncoiled ammonites.

The top of Upper greywacke member is faulted out at the point about 5/8 of a mile south (up the road) of 3rd switchback (Fig. 7). The fault zone is well marked by a more than 100 feet wide zone of strongly indurated, closely jointed and rust-to orange-weathered (? hydrothermally altered) greywacke in roadcut on left. For about ½ a mile uphill of the fault roadcuts on left expose the above described sequence of Barremian to Aptian greywacke unit in a reverse order (Fig. 7).

The not previously seen lower part of Argillite member and the contact with the Lower greywacke member are well exposed in bluffy roadcut at the point about ¼ of a mile east of the fault (Fig. 5). Some 295 feet of Lower greywacke member are exposed farther up the road. The upper 65 feet consist of light green grey sparcely fossiliferous, mostly fine grained, calcareous, hard, massive to indistinctly bedded greywacke with some pods and interbeds of medium to coarse grained, gritty and pebbly greywacke. These mid-Barremian (Jeletzky, p. 216, Fig. 1; this report, Fig. 1) beds appear to represent the same littoral to neritic environment as the fossiliferous intervals of Upper greywacke member. They appear to be the initial phase of the Jackass Mountain transgression in the eastern part of the area (Fig. 2) as the underlying about 130 feet thick partly coaly, plant-bearing beds of Lower greywacke member apparently were deposited in a beach to lagoonal environment on the marginal part of the eastern mainland prior to the arrival of Jackass Mountain sea. These nonmarine beds are believed to be younger than the Hauterivian lower part of the marine greywacke of the Lower greywacke member in Skagit Bluff section (Fig. 4; Stop 2). Lower contact is covered and faulted.

Major north-trending fault throwing the Jackass Mountain rocks against those of Ladner Group crosses the road (Fig. 5), and continues upslope to the 6th stretch of Lookout Road within a 120 feet wide covered interval of the slope on left.

Discontinuous outcrops of closely jointed, sheared and calcitveined greywacke and argillite (rust to red-weathered) of Ladner Group begin on the left southeast of the covered interval and continue for the next 800 feet up the road. Then the roadsides are covered for 800 feet to 4th switchback.

Above 4th switchback (Fig. 5) good exposures of thinly bedded greywacke and argillite of Ladner Group begin on the right. These outcrops, which continue for about 3/8 of a mile represent the uppermost exposed part of the flyschoid

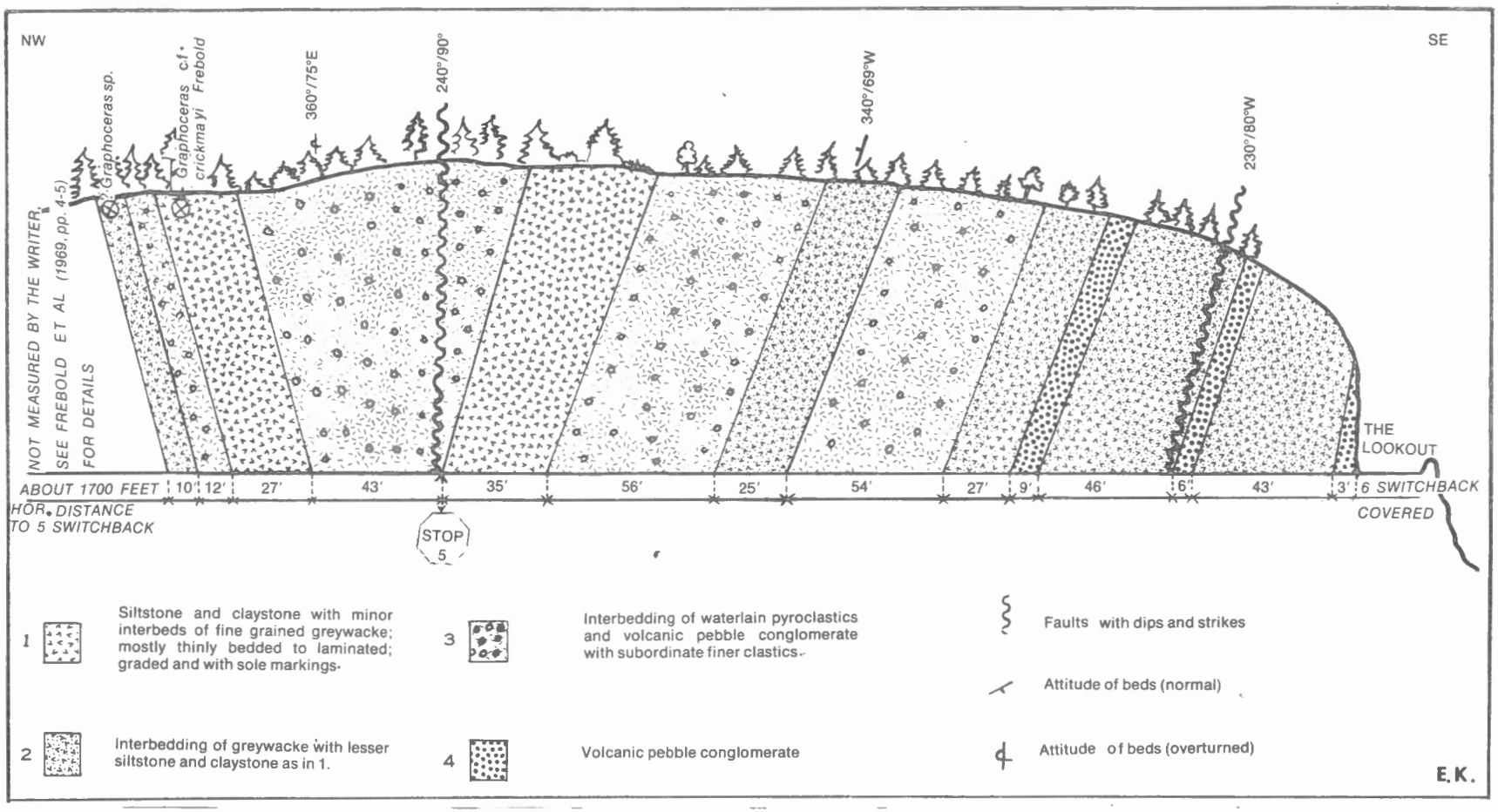

Figure 8. Section of the upper unit (Bajocian) of eastern facies of Ladner Group on Lookout Road just below the Lookout (Stop 6). View due NE (strongly oblique to strike).

eastern facies described by Coates (in Frebold et al, 1969, pp. 4-6, Fig. 2), and occur stratigraphically above the top part of the section depicted in Fig. 8.

Roadsides completely covered for about 1/5 of a mile to the 5th switchback. The previously mentioned major northwest trending fault separating Jackass Mountain and Ladner groups underlies the middle part of the covered interval (Fig. 5).

Above 5th switchback roadsides are covered for 200 feet and underlain by above mentioned fault.

Almost continuous but structurally complex exposures of cyclically alternating mostly thinly bedded to laminated volcanic sandstone, siltstone and shale of Ladner Group occupy bluffy roadcuts on the left in the interval 200 feet to 1700 feet above 5th switchback. The section exposes the same sequence as that seen on the right in the lower part of the fifth stretch of Lookout Road but in reverse (a downward sequence) order. This section ends in a 200 to 300 feet wide fault zone of closely jointed, partly contorted, rust to orange-weathered rocks marked in Fig. 5.

Stop 5

Leave buses at point about 1,700 feet above 5th switchback and proceed on foot for about 3/8 of a mile to "The Lookout" (or the 6th switchback).

The above mentioned fault zone (Fig. 8) forms the top of an about 400 feet thick section representative of upper beds of the eastern facies of Ladner Group. The direction of Lookout Road is strongly oblique to the true dip of beds (Fig. 5).

The rocks are early middle Jurassic or middle Bajocian (equivalents of Otoites sauzei and Sonninia sowerbyi zones; Frebold et al., 1969, pp. 32-33)

throughout as diagnostic ammonites occur in the uppermost and lowermost beds exposed.

Unlike the about contemporary western flysch facies of Ladner Group (see Fig. 3 and Stop 1) the eastern facies is dominated by coarse to fine grained arenites and rudites poor or lacking in features diagnostic of true turbidites and exhibiting locally features suggestive of a shallow water to nonmarine deposition. These rocks may be fluxoturbidites in part at least. Only the mostly minor interbeds of thinly and regularty bedded and laminated, more or less distinctly graded and sole marked, fine grained arenites and argillites appear to be true turbidites. See pp. 3-4 of the Introduction for further details.

The basal 50 feet of the section exposed on both sides of the entrance to the Lookout are especially rich in features diagnostic of shallow water to nonmarine environment, including ripple marks, scour channels, presence of small pods and thin interbeds of apparently autochtonous impure coal, and abundance of fossil wood (including large twigs ans sizable tree trunks). The lithology of these beds is transitional to that of middle to ? lower beds of the eastern facies depicted in Fig. 9 (see in description of Stop 6).

The Lookout offers a unique panorama of Northern Cascades directed toward the International Boundary. After a brief stop to enjoy the view, board the buses and resume the trip.

For about 1/3 of a mile upslope from the Lookout the bluffy roadcuts on the left expose the basal part of the already traversed (Fig. 8) sequence of the upper Ladner Group.

A bed of intensively crossbedded and ripple-marked, tuffaceous siltstone containing mid-Bajocian ? Stephanoceras (Skirroceras) sp. and Graphoceras cf. crickmayi Frebold occurs in the bluffy roadcut on the left about 140 yards up the road from entrance to Lookout.

The contact with the conglomeratic middle beds of Ladner Group is exposed on left at the end of this interval. The exposures of these conglomeratic beds continue for the next 1/6 of a mile upslope to the sharp right turn of the road. After this sharp turn (Fig. 5) the road continues on a southeastern course for about 1/5 of a mile to the 7th switchback (Fig 5). Roadcuts on left expose the conglomeratic and volcanic rocks of the middle beds of eastern facies of Ladner Group equivalent to those exposed in the section above 7th switchback (Fig. 9).

Stop 6

Leave buses at the upper (northwestern) side of 7th switchback and proceed on foot for about 1/4 of a mile up the road to inspect the about 920 feet thick section of the middle beds of Ladner Group summarized in Fig. 9.

The section exposed in the bluffy right side of the road is entirely older than the basal beds of the previously studied section in the 6th stretch of Lookout Road (Fig. 8). These middle beds of the eastern facies differ from its upper beds mainly in the presence of considerable units of andesitic, presumably nonmarine (absence of pillow structures) lava flows and pyroclastics (mainly coarse to fine, primary volcanic breccia). These volcanics are believed to be local lens-like bodies derived from nearby island-like volcanic centers (Coates, 1970, p. 150).

Indistinctly and irregularly bedded, poorly sorted pebble conglomerate often grading into waterlain pyroclastics strongly predominates among sedimentary types. Thinly and regularly bedded to laminated, fine grained arenaceous and argillaceous rocks are reduced to a few thin interbeds. This section appears to consist largely a shallow water (? or beach deposits) to nonmarine deposits

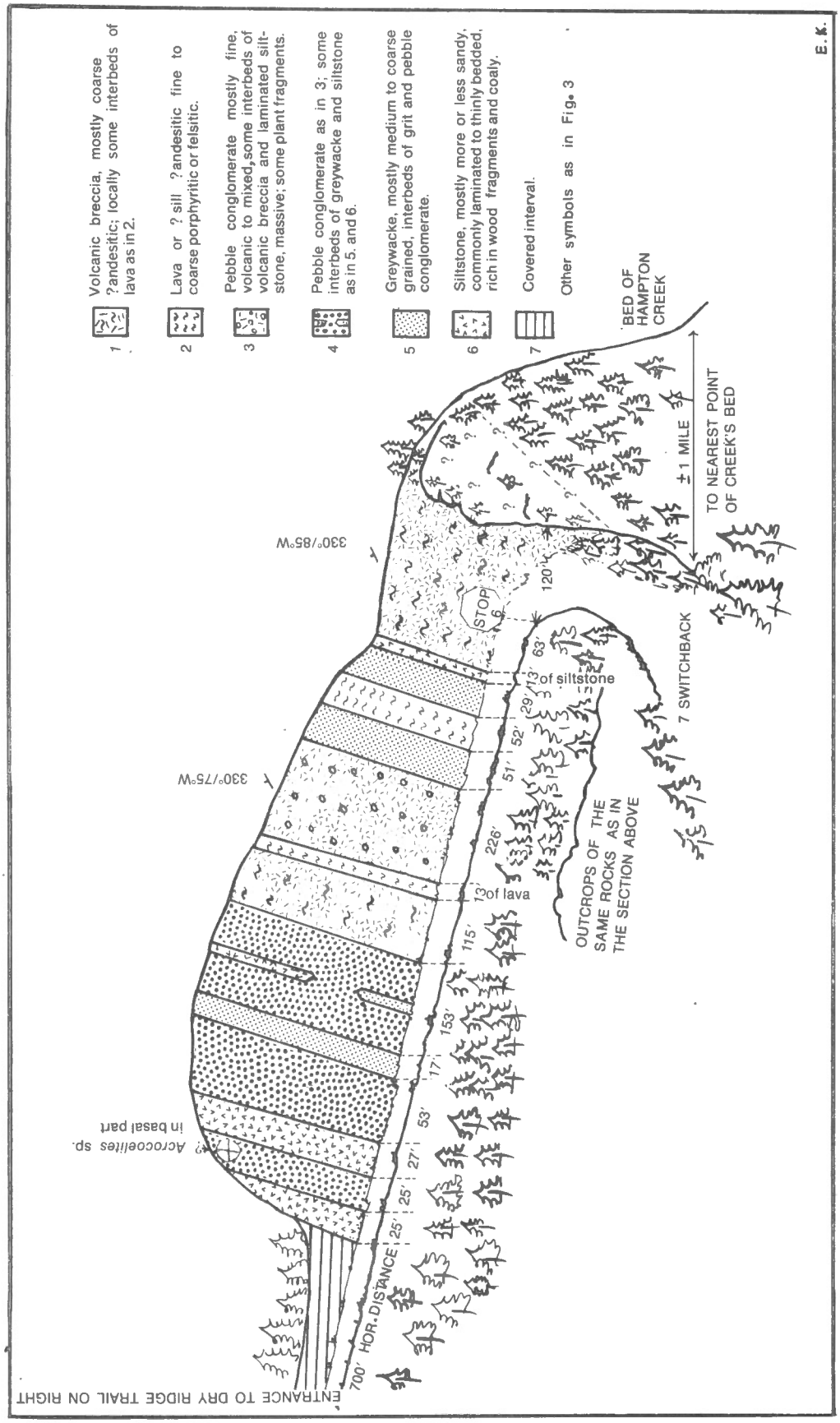

Figure 9. Section of the middle (?Toarcian and ?older) part of Ladner Group in the lower part of 8th stretch of Lookout Road between 7th switchback and the entrance to Dry Ridge Trail. View due W.

for reasons given in pp. 4-5 of the Introduction.

Rare belemnites occurring in the uppermost beds of the section (Fig. 9) were identified tentatively as Acrocoelites sp. indet. This suggests a late Toarcian or ? early Bajocian (= Aalenian) age for these beds.

Board buses at the point about ¼ mile above 7th switchback (close to entrance to Dry Ridge Trail on left) and resume the trip.

Intermittent outcrops of mostly conglomeratic rocks of the middle beds of eastern facies continue in roadcuts on the right and on the left for the next 3/8 of a mile almost to the 8th switchback (Fig. 5). The road moves steadily upsection. The beds approximately corresponding to the basal beds of the Lookout section (Fig. 8) are believed to reappear at the 8th switchback.

Above the 8th switchback the road maintains an eastern course for about 3/8 of a mile and recrosses in a descending order all of the middle beds of Ladner Group exposed between 7th and 8th switchback. The primary volcanic breccia previously seen at the 7th switchback (Fig. 9) is only doubtfully exposed at the 9th switchback at the end of this interval.

The about ¼ mile long, west-trending stretch of the Lookout Road following the 9th switchback should recross the middle beds of Ladner Group apparently equivalent to the mostly conglomeratic rocks immediately overlying the primary volcanic breccia unit at Stop 6 (see Fig. 9) and on the southern side of the 9th switchback. Intermittent outcrops consist, however, largely of interbedded arenaceous and argillitic rocks similar to those of the upper beds of Ladner Group exposed between Stop 5 and the Lookout (see Fig. 8). Coates (1970, p. 150) explains this phenomenon by a facies change away from an island-like volcanic center. However, it may be caused by an unexposed major northwest-trending fault with the downthrown northeastern side in the writer's opinion.

The following about ½ mile long, northwest-trending stretch of the Lookout Road is almost in the strike of Ladner Group. Intermittent exposures of the same arenaceous and argillitic rocks as last occur in roadcuts on the left. Some ?late Toarcian ? or early Bajocian belemnites (GSC loc. 64873) have been found at the end of this interval in an argillitic interbed on the left.

After a gentle turn to northeast the road begins to move downsection again. Scattered outcrops of the same arenites and argillites as last continue in roadcuts on the left for the next 3/5 of a mile. Then follows a slightly shorter, virtually covered interval harbouring a major approximately west-trending fault (Fig. 5). This interval continues to Blackwall Peak.

A roadcut in the bluffy southeastern face of Blackwall Peak exposes 250 to 300 feet of closely jointed and sheared, speckled green to lavender pyroclastics (mainly coarse to fine volcanic breccia devoid of pillow sturctures). Neither top nor base are exposed. This volcanic unit is believed to be older than that exposed at the 7th switchback and to represent the oldest exposed (?Sinemurian) part of Ladner Group faulted against the adjacent arenite-argillite beds (Fig. 5).

Following a 150 to 200 feet almost covered interval a roadcut on the left exposes 30 to 40 feet of disturbed dark grey argillaceous rocks (Fig. 5). These argillites contain a shallow water (?) Sinemurian fauna (GSC loc. 64872) including: "Rhynchonella" ex aff. alemanica Roll., "Rh" ex aff. baksanensis Mojsisovics. Trigonia (s. lato) sp. indet., ? Vanicoro sp. indet. and an indeterminate regular echinoid.

The road crosses a 500 yards covered interval underlain by the northwest-trending Chuwanten Fault Zone, which apparently thrusts Ladner Group on the Pasayten Group from southwest (Coates, 1970, Fig. 13-7).

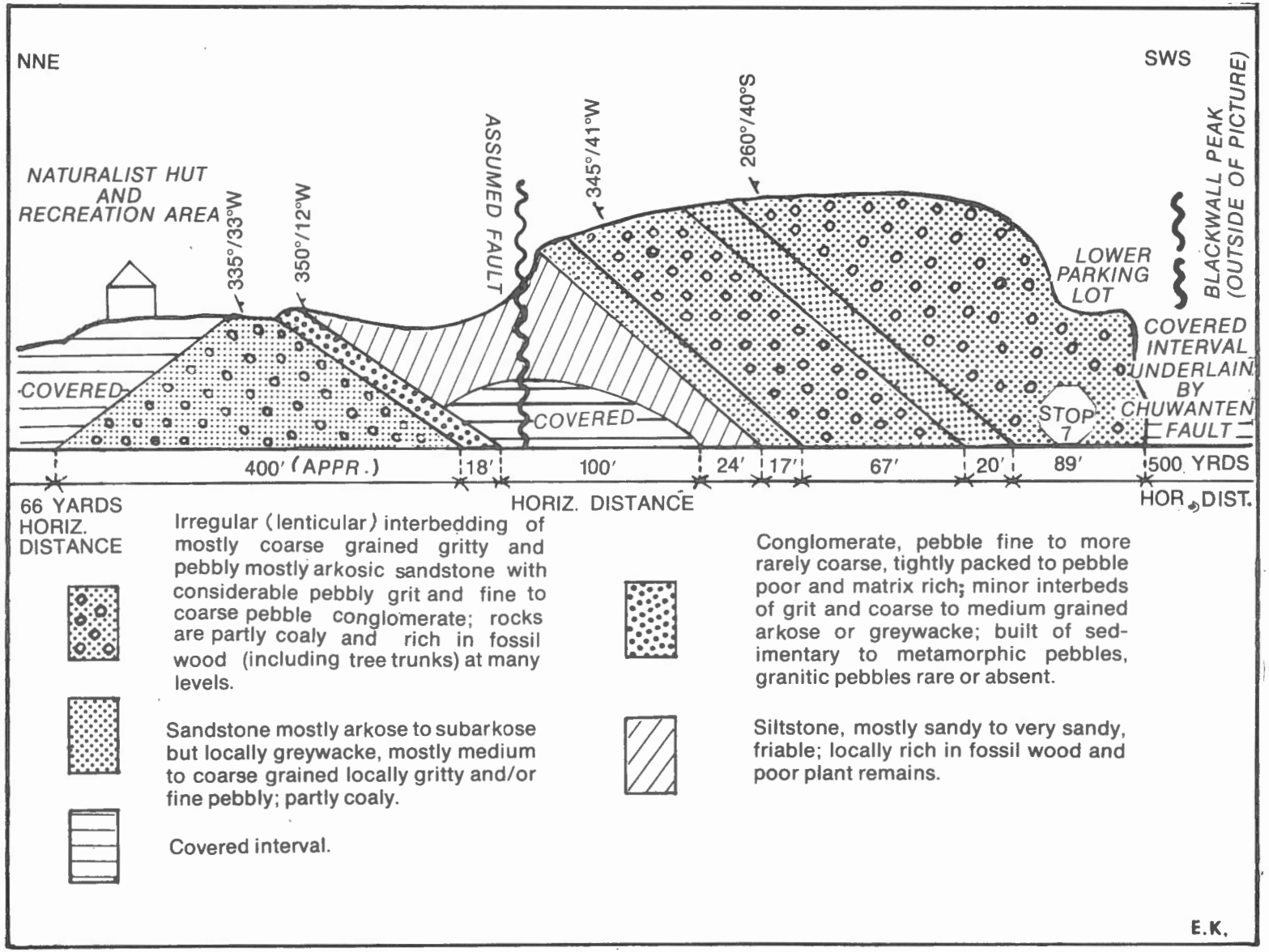

Figure 10. Section of the Upper (conglomeratic) unit of Pasayten Group exposed in roadcuts on the right (east) side of Lookout Road between the NE slope of Blackwall Peak and the Naturalist Hut at the upper end of the road.

Outcrops of the conglomeratic, upper unit of Pasayten Group begin on the right at the parking lot situated opposite the entrance to the Heather Trail (Buck Mountain Jeep Road). These rocks have been previously mapped as the "Neocomian(?)" beds by Coates (1970, p. 150, Fig. 13-4).

Stop 7

Leave buses at the Lower Parking Lot of Alpine Meadow Area and proceed on foot for about 1/6 of a mile north to the Naturalist's Hut to inspect the section of the upper unit of Pasayten Group in roadcuts on the right side of Lookout Road (Fig. 10).

The section exposes about 630 feet of predominantly coarse to medium grained, gritty and pebbly, lithologically diverse nonmarine arenities ranging from typical light grey arkose to greywacke and contrasting strongly with the older Mesozoic rocks of the area. Strings of pebbles, 1 inch to 5 feet thick pods, lenses and lenticular beds of fine to coarse grit and pebble conglomerate abound at most levels. The bedding is, as a rule, extremely irregular and sorting is poor to very poor. Clay balls are common at several levels. The rocks are characteristically carbonaceous to coaly and contain wood and locally some poor plants. Marine fossils are totally absent.

For reasons explained on pp. 10-11 of the Introduction these fluviatile, molasse-like rocks must have been deposited in an isolated entirely nonmarine depositional basin by fast east-flowing streams. These streams have been eroding the post-Lower Cretaceous tectonic land which arose west of the area following the general inversion of Tyaughton Trough.

The crest of the rounded ridge next east to the Naturalist's Hut and surrounding recreational area is underlain by mostly poorly exposed older beds of the upper unit of Pasayten Group. The middle part of the slope east of this ridge exposes the red-coloured arenaceous to argillaceous rocks of the middle unit of Pasayten Group dipping under the basal beds of its upper unit. The lower unit of Pasayten Group, including some marine interbeds with Albian ammonites, is well exposed on the eastern slopes of Three Brothers Mountain about 4½ miles north of the Naturalist's Hut.

The recreational area surrounding the Naturalist's Hut affords an unrivaled panorama of Northern Cascades.

After a brief stop to enjoy the view of surrounding mountains and the Alpine Meadows Area board buses and return to Manning Park Lodge.

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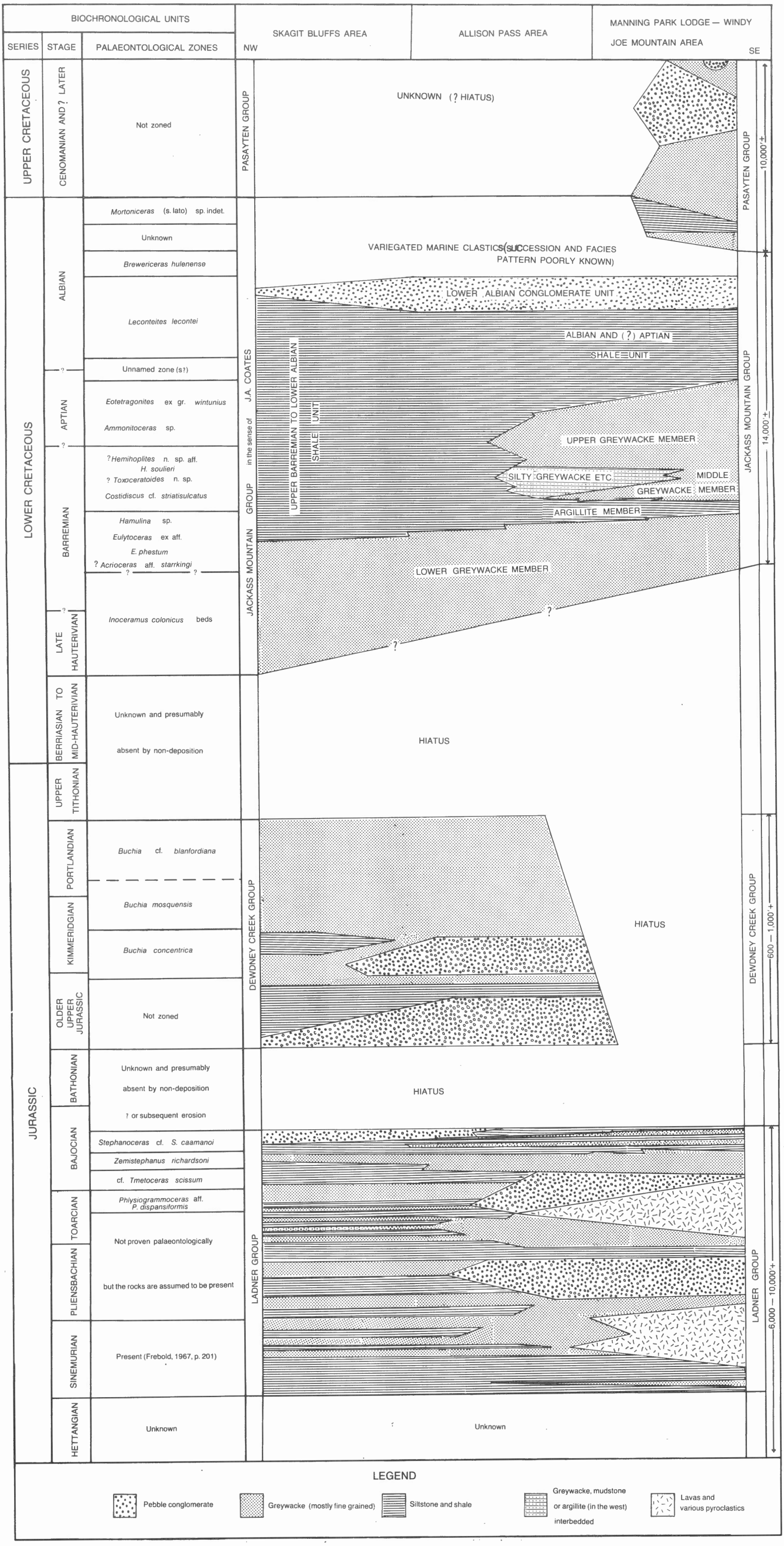

Figure 1. Suggested age and facies relationships of the Mesozoic rocks of Manning Park area, British Columbia. Not to scale and very strongly simplified in details.