Revised stratigraphic nomenclature and age determinations for mid-Cretaceous volcanic rocks in southwestern British Columbia

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Mid-Cretaceous volcanic and volcaniclastic rocks in southwestern British Columbia, east of the Fraser Fault System, constitute two principal lithostratigraphic units. The lower unit, a composite succession of basaltic to rhyolitic lavas and various clastic rocks, is exposed in a 215 km linear belt from near Pavilion to south of Princeton. The upper unit, mostly amygdaloidal andesite, is restricted to the centre of the belt between Spences Bridge and Kingsvale, where it overlies the lower unit and contiguous basement rocks. Both units were deposited subaerially, concurrent with folding and faulting, and share a contact that varies from gradational, near Kingsvale, to unconformable, near Spences Bridge.

The names ''Spences Bridge Group'' and ''Kingsvale Group'' were used by several authors for various parts of the volcanic stratigraphy. We suggest revision of nomenclature whereby the lower and upper units are named ''Pimainus Formation'' and ''Spius Formation'', respectively; together they constitute the Spences Bridge Group. The term ''Kingsvale Group'' is abandoned.

Assemblages of fossil leaves and palynomorphs, collected from one Spius and seven Pimainus localities, include several species of early angiosperms. A late Albian age is thereby indicated for both formations; this is largely corroborated by isotopic dates from the volcanic strata and cross-cutting granitic plutons.

Les roches volcaniques et volcanoclastiques du Crétacé moyen dans le sud-ouest la Colombie-Britannique, à l'est du système de failles Fraser, sont forméees de deux unités lithostratigraphiques principales. L'unité inférieure, une succession composite de laves basaltiques et rhyolitiques et de diverses roches clastiques, est exposée dans une ceinture linéaire de 215 km, partant près de Pavilion jusqu'au sud de Princeton. L'unité supérieure, composée en majeure partie d'andésite amygdaloïdale, n'apparaît qu'au centre de la ceinture entre Spences Bridge et Kingsvale, où elle recouvre l'unité inférieure et les roches du socle contiguës. Les deux unités sont d'origine subaérienne, contemporaines du développement des plis et des failles, et leur contact varie de gradationnel, près de Kingsvale, à discordant, près de Spences Bridge.

Les appelations de « Groupe de Spences Bridge » et de « Groupe de Kingsvale » ont été utilisées par plusieurs auteurs pour représenter différentes portions de la stratigraphie volcanique. Nous suggérons une révision de la nomenclature où les unités inférieure et supérieure sont appelées « Formation de Pimainus » et « Formation de Spius », respectivement; réunies, elles constituent le Groupe de Spences Bridge. Le terme « Groupe de Kingsvale » est abandonné

Les assemblages de feuilles fossiles et palynomorphes, collectés sur un site de Spius et sur sept sites de Pimainus, incluent plusieurs espèces d'angiospermes primitives. Un âge albien tardif est par conséquent assigné aux deux formations, ce qui est fortement corroboré par des dates isotopiques fournis par les strates volcaniques et le recoupement par les plutons granitiques.

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Introduction

Mid-Cretaceous volcanic rocks in southwestern British Columbia, east of the Fraser Fault System, form a 215 km north-northwest-trending belt extending from 50°46'N, near the settlement of Pavilion, to almost 49°N (Figs. 1, 2). They overlap the Cache Creek and Quesnel terranes; correlative deposits to the northwest, west of the Fraser Fault System, lie on Stikinia. Part of the mid-Cretaceous succession was named ''Spences Bridge Group'' by Drysdale (1914) from exposures near the town of Spences Bridge, at the confluence of the Thompson and Nicola rivers (Fig. 2*a*). Rice (1947) named a second, apparently overlying sequence of Cretaceous rocks the ''Kingsvale Group,'' from an inferred type locality along the Coldwater River near the settlement of Kingsvale (Fig. 2*b*). Subsequently, both terms were used by Duffell and McTaggart (1952) and later authors. However, the application of nomenclature to lithostratigraphic units varied among authors, resulting in an apparently chaotic history of usage. Because most studies were concentrated between the Fraser Fault System and the town of Merritt, especially along the Thompson and Nicola river valleys (e.g., Duffell and McTaggart 1952; Jorgensen 1973; Devlin 1981; Monger 1981, 1982; Monger and McMillan 1984; Smith 1986), the petrology and field relations of rocks in that area (Fig. 2*b*) were known in greatest detail. Conversely, rocks in the ''type area'' of the Kingsvale Group, despite the use of the ''Kingsvale'' term by other authors, had not been studied since the work of Rice (1947).

This paper is based on our recent investigations between Spences Bridge and Kingsvale, herein called the study area and defined by Fig. 2*b*. Greatest emphasis was placed on rocks within 10 km of Kingsvale. We attempt to delineate the evolution of stratigraphic names and place previous authors' terminology in a historical context. We review correlations between the various Cretaceous volcanic units and propose new lithostratigraphic nomenclature. Palynology and paleobotany provide new estimates of age.

Revision of lithostratigraphic nomenclature

Previous work

Cretaceous volcanic rocks in the region shown in Fig. 2*a*, were first investigated by Dawson (1879, 1895, 1896), who assigned them to the Miocene. Drysdale (1914) studied the

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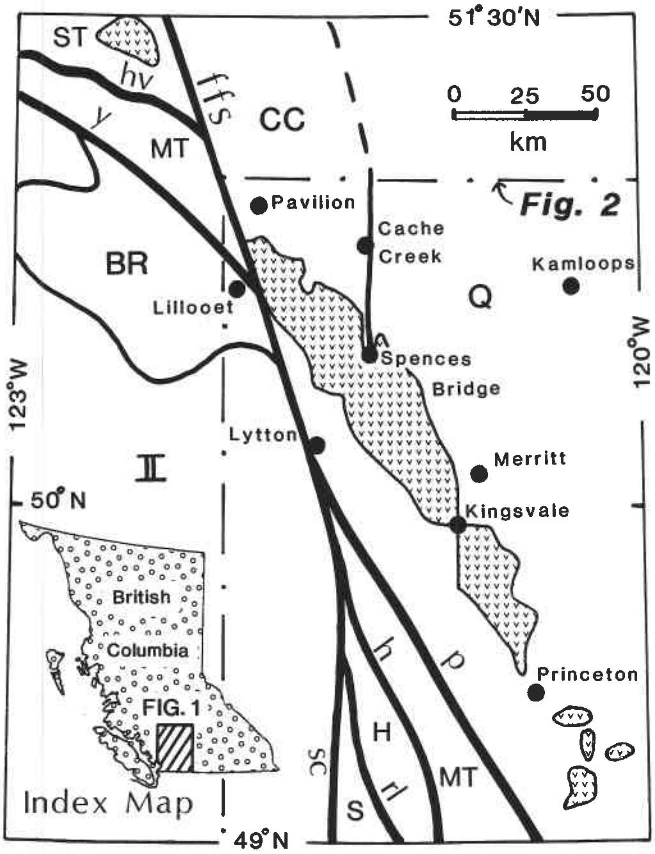


FIG. 1. Distribution of Spences Bridge Group (revised nomenclature) and correlative rocks in relation to major terranes, faults, and settlements (after Monger 1985; Kleinspehn 1985; Mathews and Rouse 1984). Terranes: BR, Bridge River; CC, Cache Creek; H, Hozameen; MT, Methow–Tyaughton; Q, Quesnellia; S, Skagit; ST, Stikinia; II, terrane II and others. Faults: ffs, Fraser Fault System; y, Yalakom; hv, Hungry Valley; p, Pasayten; h, Hozameen; sc, Straight Creek; and rl, Ross Lake.

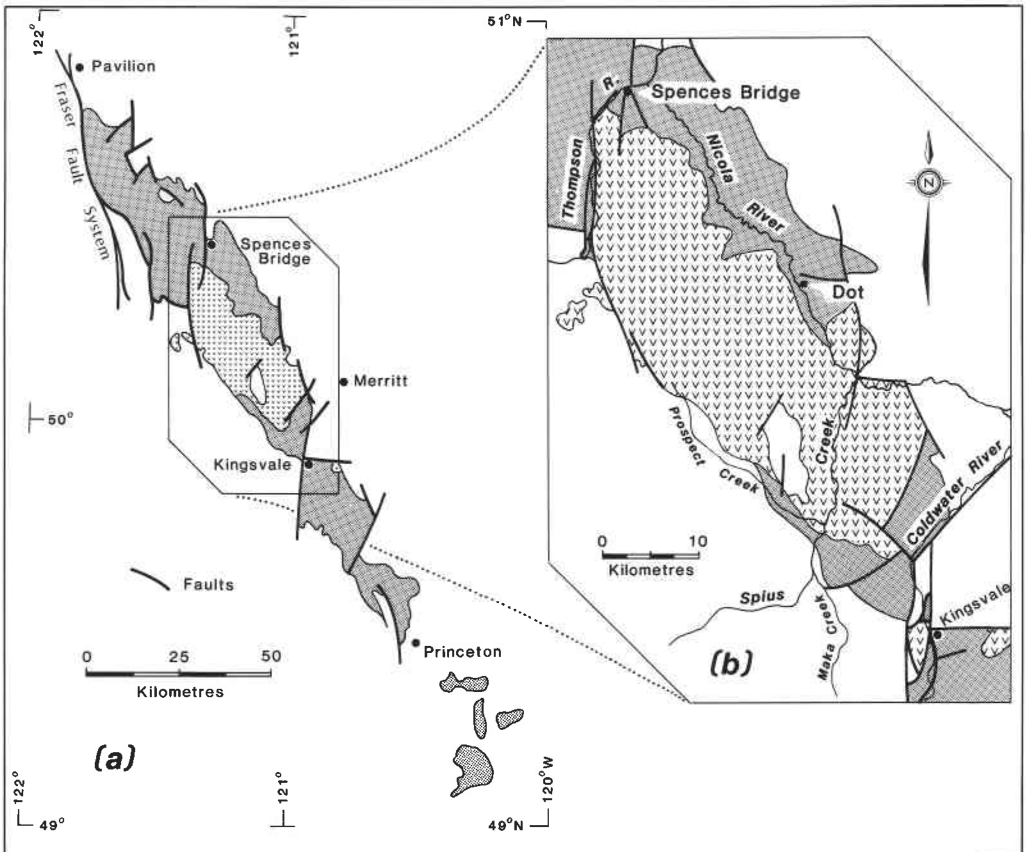
rocks in greater detail along the Thompson and Nicola rivers and recognized two fundamental stratigraphic units. He named the lower unit, a sequence of basaltic to rhyolitic flows intercalated with tuff and sandstone, the "Spence Bridge Volcanic Group," a usage followed (omitting "Volcanic") by Rice (1947). Duffell and McTaggart (1952) and all later authors used the adjusted spelling "Spences" to be consistent with the settlement of Spences Bridge.

Although he did not specify a type section or locality from within the roughly 400 km^2 mapped as Spences Bridge Group, Drysdale discovered a single fossil locality yielding plants of apparently Jura-Cretaceous age (Knowlton *in* Drysdale 1914; Wilson *in* Drysdale 1914). Thickness of the Spences Bridge Group was estimated by Drysdale at 1550 m.

The upper unit, observed by Drysdale (1914) to lie on both the Spences Bridge Group and contiguous basement rocks, comprises a sequence of mostly uniform, reddish brown andesite flows hosting abundant amygdules of quartz, chalcedony, calcite, and zeolites. Drysdale followed Dawson (1896) by correlating those flows with the Tertiary Kamloops Group. Correlation of nomenclature for Drysdale (1914) and later authors is shown in Fig. 2. Rice (1947) studied Cretaceous rocks southwest of Drysdale's (1914) type area. In addition to the Spences Bridge Group, Rice reported the existence of a second, largely clastic, composite volcanic section of rocks apparently unconformably overlying the Spences Bridge Group. The presence of clasts of Spences Bridge Group lava within that section suggested to Rice that the clastic rocks were a younger deposit derived in part by erosion of the Spences Bridge Group. Plant fossils collected from these rocks near Kingsvale (Fig. 2*b*) were examined by W. A. Bell, who reported an Albian (latest Early Cretaceous) age (Bell *in* Rice 1947; Bell 1956). Bell also re-examined Drysdale's (1914) collection of fossils, giving them an Aptian (one age older) age (Bell *in* Rice 1947). These age assignments supported Rice's field interpretations and led Rice to separate the apparently younger and overlying rocks from the Spences Bridge Group and to name them "Kingsvale Group" (Rice 1947). Like Drysdale, Rice did not specify a type section, and it is therefore by inference that the Kingsvale Group type area is located in the vicinity of his most diverse fossil locality, immediately south of Kingsvale, west of the Coldwater River.

The name "Kingsvale Group" was subsequently used by several authors to describe a variety of rocks in southwestern British Columbia. Cockfield (1948) followed Rice (1947) and mapped all of the upper, amygdaloidal package and most of the Spences Bridge Group as Kingsvale Group. Duffell and McTaggart (1952) re-examined the units mapped by Drysdale (1914). They described a sequence of sedimentary beds separating the Spences Bridge Group from the overlying amygdaloidal andesite unit (Drysdale's Kamloops Group) southeast of Spences Bridge along the Nicola River. Those strata, comprising well-bedded sandstone, siltstone, mudstone, conglomerate, and tuff, which represent a dominantly fluvial and lacustrine environment (Devlin 1981), will be referred to as the "Dot beds," named (informally) from the settlement of Dot near which those beds are well exposed (Figs. 2*b*, 3). Plant fossils from the Dot beds were determined by Bell to be of Albian age (Bell *in* Duffell and McTaggart 1952). The similarities in floral types and assigned age between these rocks and Rice's Kingsvale locality led Duffell and McTaggart (1952) to apply the name "Kingsvale Group" to both the Dot beds (basal Kingsvale Group) and the overlying amygdaloidal volcanic sequence (upper Kingsvale Group), thereby abandoning previous correlations with the Kamloops Group. Maximum thicknesses were estimated by Duffell and McTaggart (1952) to be about 300 m for the Dot beds and 1300 m for the entire Kingsvale Group.

More recently, Jorgensen (1973) studied the Spences Bridge Group and the basal Kingsvale Group of Duffell and McTaggart (1952) northeast of the Nicola River between Spences Bridge and Merritt. Based on similarity in lithology and attitude he concluded that the Dot beds were simply a continuation of the Spences Bridge Group. Preto (1979) mapped two units between Princeton and Merritt as Kingsvale Group (Fig. 2*a*). Monger (1981) followed Jorgensen by correlating the Dot beds with the Spences Bridge Group and suggesting that the entire sequence, including the upper amygdaloidal unit, should be considered a single stratigraphic package. However, south of Spences Bridge near Soap Lake, Devlin (1981) described an angular unconformity separating the upper Kingsvale Group of Duffell and McTaggart (1952) from the underlying Spences Bridge Group and consequently regarded the amygdaloidal andesites as a separate unit. Devlin followed Monger's (1981) correlation of the Dot beds with the Spences Bridge Group, thereby restricting his usage of Kingsvale Group to the upper lavas. He noted Duffell and McTaggart's (1952) correlation of



upper Albian	PREVIOUS NOMENCLATURE	REVISED NOMENCLATURE
Reddish brown to green and black, amygdaloidal to dense andesitic flows; minor pyroclastic and epiclastic rocks	• Amygdaloidal andesite unit of Thorkelson (1985) • Kingsvale Group of Monger (1985, 1982, 1981); Monger and McMillan (1984); Devlin (1981) • Upper Kingsvale Group of Duffell and McTaggart (1952)	**Spius Formation** (Spences Bridge Group)
upper Albian Varicoloured andesitic to rhyolitic flows; welded and nonwelded ignimbrite, tuff, lahar, conglomerate, sandstone, mudstone, and coal	• Spences Bridge Group of Thorkelson (1985); Monger (1985, 1982, 1981); Monger and McMillan (1984); Devlin (1981) • Kingsvale Group (unit 10) of Preto (1979) • Spences Bridge Group and basal Kingsvale Group of Duffel and McTaggart (1952) • Spences Bridge Group and Kingsvale Group of Rice (1947) • Spences Bridge Group of Drysdale (1914)	**Pimainus Formation** (Spences Bridge Group)

FIG. 2. Distribution of the Spences Bridge Group and its constituents, the Pimainus and Spius formations (revised nomenclature). (*a*) Regional map of the Nicoamen Structural Depression (after Monger 1985). (*b*) Distribution in the study area (after Monger 1985; Thorkelson 1985, 1986).

the Dot beds with Rice's Kingsvale Group and concluded that Rice's Kingsvale Group must also be part of the Spences Bridge Group. This observation threw the validity of Rice's nomenclature into question and was a primary reason for our subsequent investigation of the Cretaceous rocks near Kingsvale. Monger (1982, 1985) and Monger and McMillan (1984) concurred with Devlin (1981) and reserved the term "Kingsvale Group" for the upper succession of amygdaloidal lava. Thorkelson (1985) used the informal term "amygdaloidal andesite unit" for the Kingsvale Group of Monger and McMillan (1984) and used the informal term "lower Spences Bridge Group" (Thorkelson 1986) for the Spences Bridge Group of Drysdale (1914).

The need for revised nomenclature

Recent work near Kingsvale has shown that rocks defined as Kingsvale Group by Rice (1947) are inseparable from rocks of the Spences Bridge Group (Thorkelson 1985). About 5 km southwest of Kingsvale, in the vicinity of Fig Lake, typical Spences Bridge Group andesite and rhyolite (as identified by Rice 1947) stratigraphically overlie the clastic rocks containing the fossils collected by Rice at Kingsvale. The Spences Bridge Group therefore hosts both these fossils and those collected by Drysdale (1914). Furthermore, Rice's belief that the Kingsvale clastic rocks are composed of erosional detritus shed from Spences Bridge Group rocks after cessation of Spences Bridge Group volcanism appears to have been based

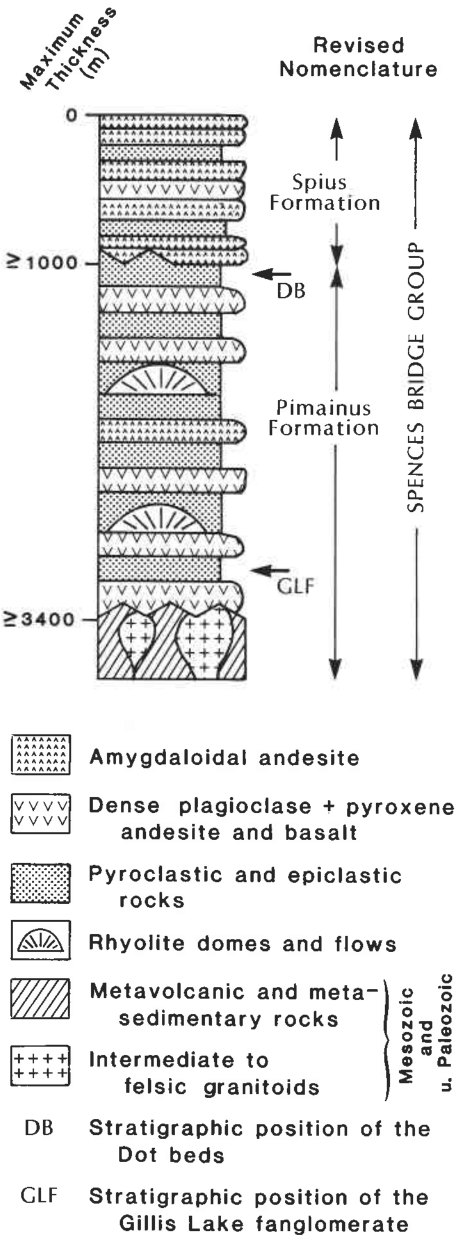


FIG. 3. Generalized stratigraphy of the Spences Bridge Group. Pimainus Formation, comprising intercalated clastites and lavas, uncomformably overlies late Mesozoic to Early Jurassic rocks. Spius Formation, mostly flows of amygdaloidal andesite, rests with variable conformity on the Pimainus. Note stratigraphic positions of the Dot beds and the Gillis Lake fanglomerate.

on misinterpretation of volcanic facies. A large proportion of the clastic rocks are deposits of nonwelded ignimbrite (pyroclastic flows) and lahar whose deposition was contemporaneous with adjacent extrusions of rhyolite and andesite. Also present are waterlaid epiclastic rocks, mostly arkosic sandstone and wacke, which constitute a common facies of composite volcanic sequences. Contrary to suggestions by Rice (1947), pyroclastic and epiclastic rocks are intercalated throughout the volcanic pile and are not restricted to the top of the section.

The Kingsvale Group (amygdaloidal) package of Monger and McMillan (1984) is poorly exposed in the area studied by Rice (1947). Consequently, Rice neither recognized it as a distinct unit nor classified it consistently. For instance, the amygdaloidal andesite unit exposed in the graben 1 km west of Kingsvale (Fig. 2*b*) was mapped by Rice as Neogene plateau basalt. The other two exposures in his map area, 6 km east of Kingsvale and 9 km northwest of Kingsvale (Thorkelson 1985), were both mapped as Kingsvale Group by Rice and therefore included in what is now recognized as part of the Spences Bridge Group.

The two units called Kingsvale Group by Preto (1979), located about 20 km east of Kingsvale, may actually be two different units. Preto's unit 10 is certainly part of the Spences Bridge Group (Monger 1985; Thorkelson 1985). His unit 11, however, may belong to the Triassic Nicola Group (J. W. H. Monger, personal communication, 1984).

The work of Devlin (1981) and Monger (1982, 1985) indicates that near Spences Bridge, deposition of the amygdaloidal andesite unit was preceded by a period of faulting and folding. Near Kingsvale, however, angular relations did not develop, as indicated by exposures roughly 5 km east of Kingsvale, where the lowest flow of the amygdaloidal andesite unit rests conformably on Spences Bridge Group felsic tuff and sandstone. Furthermore, stratigraphic relations are gradational about 4 km southeast of the Spius Creek – Prospect Creek confluence. Stratigraphic conformity and interfingering reveal that a hiatus did not separate deposition of these units in that region. This evidence of partial age equivalence, corroborated by recent age determinations (this paper), is a major consideration in the following section on revision of nomenclature. Petrographic and geochemical evidence for regarding these units as products of a single mid-Cretaceous pulse of magma was given by Thorkelson (1986, 1987).

Recommendations for lithostratigraphic nomenclature

The amygdaloidal andesite unit is a distinct lithostratigraphic unit that lacks a formal name and type section as required by the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature 1983). Although Duffell and McTaggart (1952) called this unit "upper Kingsvale Group," and later authors (e.g., Monger 1982) called it "Kingsvale Group," the "Kingsvale" name should not be used because the rocks Rice (1947) defined as Kingsvale Group are actually part of the Spences Bridge Group and are not correlative with the amygdaloidal andesite unit. To end the present confusion it is herein proposed that the amygdaloidal andesite unit be named "Spius Formation." The name "Spius" is from Spius Creek, along which these rocks are well exposed. The type locality is defined as the area within 2 km of Spius Creek, between Prospect Creek and the Nicola River (Fig. 2*b*).

Locally conformable and gradational relations plus similarities in age, chemistry, and some lithologies between Spius Formation and the Spences Bridge Group are convincing reasons to regard these units as a single volcanic package. We suggest revision of nomenclature such that the Spences Bridge Group is expanded to include Spius Formation as the upper part of that group. The composite section previously known as the "Spences Bridge Group" is herein called the "Pimainus Formation" of the (expanded) Spences Bridge Group, named from the Pimainus Hills northeast of Spences Bridge. It was from strata underlying the western slope of those hills, about 3 km northeast of the confluence of the Thompson and Fraser Rivers at an elevation of about 770 m, that Drysdale (1914) collected fossil leaves that yielded the first direct age determination of this formation. The importance of that area suggests that it can reasonably be regarded as the type locality of Pimainus Formation. We feel that Pimainus Formation should continue to be represented by this locality and the lithostratigraphic descriptions given by Drysdale (1914). Additional work may result in subdivision and naming of rock units within this lower, lithologically diverse package as members.

Correlations across the Fraser and Yalakom faults

The abundance of Pimainus Formation rocks immediately east of the Fraser Fault System suggests that correlative rocks are likely to be found across the fault system on the northerly displaced western side. Cretaceous volcanic rocks of rhyolitic to basaltic composition yielding K−Ar dates of 91−101 Ma were mapped north of the Hungry Valley Fault in the vicinity of Gang Ranch, British Columbia (Fig. 1) and were correlated with the Spences Bridge or Kingsvale group (Mathews and Rouse 1984). The age and petrology of such rocks suggest that they are equivalent to the Pimainus Formation (W. H. Mathews, personal communication, 1985), and their present geographic position agrees with estimates of dextral offset across the Fraser Fault System of 70−110 km (Mathews and Rouse 1984; Kleinspehn 1985, Monger 1985). Some mid-Cretaceous sedimentary rocks between the Fraser and Yalakom faults may also be correlative with the Pimainus Formation but not with the Spius Formation, which has a more restricted areal distribution and a near-absence of epiclastic rocks. Cretaceous paleogeographic reconstructions by Kleinspehn (1985) indicate that mid-Cretaceous rocks southwest of the Yalakom Fault were present about 40 km west of the Spences Bridge Group. Volcanic rocks in that region, called "Kingsvale Group" by Tipper (1978), were apparently separated from the Spences Bridge Group by the partly contemporaneous (Monger 1981; Kleinspehn 1985) Jackass Mountain Group and possibly by rocks of the Mount Lytton Plutonic Complex. Because of their paleogeographic separation and marked stratigraphic dissimilarity (Kleinspehn 1985), we suggest that volcanic rocks and associated sedimentary facies southwest of the Yalakom Fault should not be called "Spences Bridge Group." As previously stated for rocks east of the Fraser Fault System, the term "Kingsvale Group" should also be abandoned for rocks west of that fault system.

Stratigraphy

Older rocks

The Spences Bridge Group and equivalent strata unconformably overlie several rock units of the Quesnel, Cache Creek, and Stikine terranes (Fig. 1). On Quesnellia, southeast of Spences Bridge, the Cretaceous succession overlies volcanic rocks of the Upper Triassic Nicola Group and plutonic rocks of the Lower Jurassic Guichon batholith, the lower Mesozoic Mount Lytton Plutonic Complex, and other felsic to intermediate intrusions (Monger 1985; Preto 1979). Northwest of Spences Bridge, "basement" comprises sedimentary and volcanic formations of the Pennsylvanian to Lower Jurassic Cache Creek Group (Monger 1985; Duffell and McTaggart 1952). North of the Hungry Valley Fault, Pimainus correlatives rest on Stikinia (Mathews and Rouse 1984). Nowhere is the Spences Bridge Group conformable with older rocks.

Near Gillis Lake, a few kilometres west of Kingsvale, "basement" rocks comprise the Nicola Group and at least two medium-grained plutonic phases. The oldest rocks are andesitic to rhyolitic volcanic facies of the Nicola Group, typically metamorphosed to lower greenschist grade, with incipient foliation. They occur as roof pendants in dominantly plutonic rock. Grey granodiorite to diorite, the first granitoid to intrude the Nicola Group, is commonly agmatitic with dark xenoliths. Intruding both units is pink granite, commonly mylonitized, with fabric that apparently parallels its intrusive contacts. Preto (1979) reported a 203 ± 5 Ma K−Ar date from a pink granite clast in Pimainus conglomerate and 203 ± 5 and 200 ± 5 Ma K−Ar mica dates from the Allison Lake pluton, from localities north of Princeton. If those granitoids and the pink granite are correlated, then all rocks in the study area on which the Spences Bridge Group was deposited are Early Jurassic and older.

Four localities near Kingsvale attest to moderate topographic relief of basement rocks at the time of Spences Bridge Group deposition, as suggested by Rice (1947) and Drysdale (1914). Nine kilometres east-northeast of Kingsvale a paleotopographic high is evident where the two lowest strata of Pimainus Formation pinch out against plutonic basement rocks. Five kilometres south-southwest of Kingsvale, on the western slopes of Shovelnose Mountain, two inliers of granite are exposed within Pimainus Formation rhyolite and andesite (Rice 1947; Thorkelson 1986). Rice also mapped a small granitoid inlier, 10 km north of Kingsvale, west of the Coldwater River.

Stratigraphy of Pimainus Formation

Pimainus Formation comprises a diverse succession of volcanic and sedimentary rocks, which display rapid vertical and lateral facies changes. A profound lateral variation exists near Kingsvale. A few kilometres to the northwest of Kingsvale, pyroclastic and epiclastic deposits are intercalated with andesitic lava. The clastic rocks are generally felsic, implying concomitant eruption of rhyolitic magma. The mafic composition of the lava flows in this facies contrasts with deposits located a few kilometres to the southeast, on Shovelnose Mountain. There, similar clastic rocks are interbedded with lava of predominantly rhyolitic composition. Pods of rhyolite such as this are scattered throughout the Pimainus Formation (Duffell and McTaggart 1952; Jorgensen 1973; Preto 1979; Devlin 1981).

A generalized section of the Pimainus Formation, integrating stratigraphy from throughout the study area, is shown in Fig. 3. Important aspects of that section are (*i*) the unconformity or nonconformity below which sit older rocks that form the basement to the Spences Bridge Group; (*ii*) the ubiquity of andesite lava and clastic rocks of various types; (*iii*) the predominance of dense over amygdaloidal lava; (*iv*) the laterally restricted presence of rhyolite; and (*v*) the conformable to unconformable relationship with the overlying Spius Formation. As noted by Thorkelson (1985) and inferred by previous workers, the volumetric ratio between lava and clastic rocks is approximately 1:1.

The andesitic flows are typically bluish to purplish grey, dense, and plagioclase + pyroxene phyric. They commonly exhibit subtle flow banding, generally coplanar with bedding in contiguous clastic rocks and, especially on glacially polished surfaces, flow breccia. In many places the andesitic flows are columnar jointed (Fig. 4). Highly amygdaloidal varieties, much less common, host a variety of minerals such as calcite, quartz, chalcedony, chlorite, celadonite, and zeolites, whose stability fields indicate zeolite metamorphic

FIG. 4. Columnar-jointed flow of Pimainus andesite above Otter Creek, 18 km southeast of Kingsvale.

grades (Drown 1973; Mamu 1974; Pearson 1974; Devlin 1981; P. B. Read, personal communication, 1986).

Rhyolites are two main varieties: high-silica, light grey flows with quartz + plagioclase + hornblende or pyroxene phenocrysts; and low-silica mauve to black rocks with plagioclase + pyroxene phenocrysts. Both types usually display contorted flow bands, although some low-silica flows are columnar jointed with planar flow bands. In places, such as 6.5 km southeast of Kingsvale, rhyolites appear to form domes, representing eruptive centres.

Clastic rocks include a variety of lithologies, both pyroclastic and epiclastic, and are ubiquitous throughout the distribution of Pimainus Formation. The most abundant lithologies are poorly sorted and weakly to nonstratified deposits containing clasts of Pimainus andesite, rhyolite, and volcaniclastic rocks and occasionally basement lithologies. These rocks are interpreted as lahar and nonwelded ignimbrite. (''Ignimbrite'' is used here for all pyroclastic flow deposits, as suggested by Fisher and Schmincke (1984, p. 222).) Such deposits can be difficult to distinguish from one another and may physically grade from ignimbrite to lahar with increasing distance from the eruptive vent (Pierson 1985). Rocks containing primarily monomictic, angular clasts of andesite or rhyolite in a finer matrix hosting unabraded plagioclase crystals are probably ignimbrite. Lahar can, in places, be confidently identified by the presence of polymictic, rounded boulders in a dark, apparently muddy matrix. Other clastites include air-fall tuff, conglomerate, sandstone, mudstone, and welded ignimbrite hosting fiamme.

A good example of welded ignimbrite containing chloritized fiamme is found in a railway cut east of the Coldwater River, 6 km south of Kingsvale. Lahar is best seen in a Coquihalla Highway roadcut 0.5 km southeast of Kingsvale, where a 35 m deposit separates sequences of interbedded coal, tuff (including accretionary lapilli), and sandstone (Fig. 5). Rare plane beds and dunal or antidunal structures, 9.5 km northwest of Kingsvale (Fig. 6), are suggestive of base surge or lateral blast processes (Fisher and Schmincke 1984). Sandstone and mudstone, often dark and occasionally hosting fossil leaves, are scattered throughout the volcanic pile but are best developed in the Dot beds (Fig. 3); an excellent exposure of dark lacustrine strata is present in a roadcut directly above the southwestern bank of the Nicola River, west of Dot.

Conglomerates and breccias of dominantly basement lithologies are present 4.5 km northwest of Kingsvale, just west of Gillis Lake (Fig. 3). There, subrounded to angular cobbles and boulders of greenstone and granitic plutonic rock, some exceeding 2 m, constitute a predominantly clast-supported deposit that varies from 0 to 100 m in thickness within 1 km (Fig. 7). That immaturity and the large fluctuation in thickness suggest that the conglomerate was deposited in fans from nearby fault escarpments or from otherwise tectonically dis-

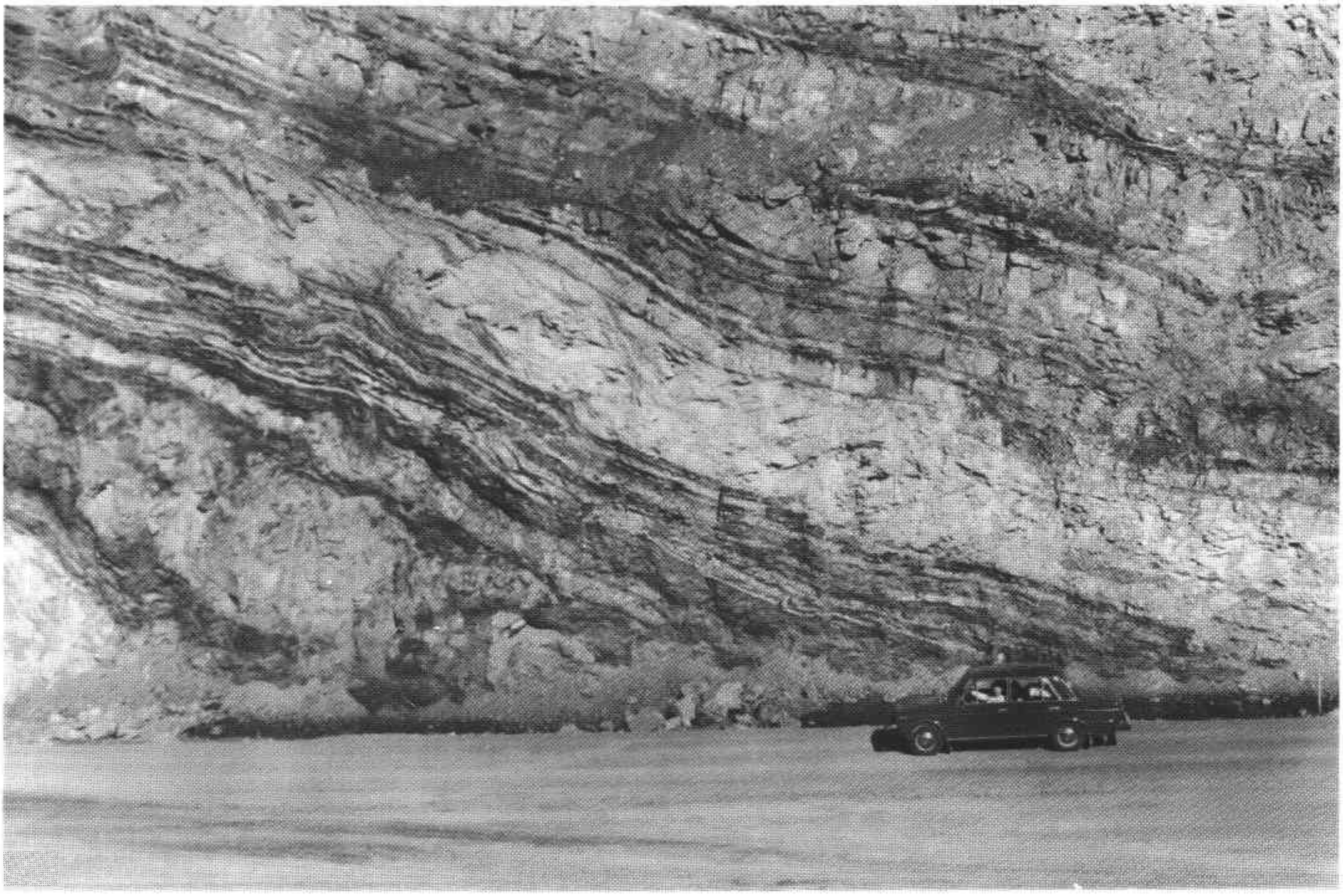


Fig. 5. Coal and interbedded volcaniclastic wacke of Pimainus Formation in Coquihalla Highway roadcut, 0.5 km southeast of Kingsvale. This section, fossil locality MVT85-24 (Table 1), produced early angiosperm leaves. Directly above the sequence is thick lahar overlain by additional coal, sandstone and tuff.

turbed basement rock. Underlying that unit is a basal flow of typical Pimainus andesite. The absence of fanglomerate below the basal flow indicates that the inferred deformation commenced after initial eruption of Pimainus lava. Similar basement-clast conglomerates in Pimainus strata are present north of Princeton (Preto 1979) and northwest of Princeton near Halfway and Goose lakes.

The thickness of Pimainus Formation in the Kingsvale area, at least 2400 m, exceeds the 1550 m estimated in the Spences Bridge area (Drysdale 1914; Duffell and McTaggart 1952).

Stratigraphy of Spius Formation

Lithologies of Spius Formation are much less diverse than those of the Pimainus Formation. They consist of dominantly reddish to yellowish brown, green, and grey amygdaloidal andesite, with lesser amounts of black to brown, dense andesite and dark pyroclastic and epiclastic rocks. Many of the lavas are aphyric except for serpentine-after-olivine pseudomorphs, although others contain plagioclase and pyroxene crystals. Vesicles are filled by the same low-metamorphic-grade minerals as in the Pimainus Formation. In contrast to the dense varieties of lava, which are commonly quite fresh, the amygdaloidal rocks are usually extremely altered, owing to their high porosity and permeability to groundwater. Dense lava commonly constitutes chilled flow bottoms, although some entire flows of this type, especially those bearing plagioclase and pyroxene, are present. Spius Formation lavas are rarely flow banded, and nowhere were columnar joints observed. No vertical or lateral trends have been reported by previous authors or observed by us. Because of this uniformity, Spius Formation was mapped almost entirely as a single unit by all previous workers and nearly so by ourselves; a discussion of detailed stratigraphy is not possible. Minimum thicknesses of Spius Formation were estimated as 600 m in the study area (Thorkelson 1985) and 1000 m near Spences Bridge (Duffell and McTaggart 1952).

The best exposures of Spius Formation are found in cliffs above Prospect Creek, at the south end of the Spius type locality, where lava flows are interbedded with coarse, mafic, autoclastic and possibly pyroclastic breccia (Fig. 8). Good exposures are also present as roadcuts along main logging routes on both sides of Spius Creek.

Flows of a Spius Formation outlier conformably overlie felsic tuff and organic-rich sandstone of the Pimainus Formation, 5.5 km east of Kingsvale (palynomorphs extracted from that sandstone are discussed later). Exposures of Spius Formation in this area are confined to small roadcuts. Immediately west of Kingsvale, good exposures are found in the canyon of Gillis Creek and on a cliff immediately east of a gas pipeline cut, south of the Gillis Lake road. North of Gillis Creek, Eocene Kamloops Group conglomerate unconformably overlies or is faulted against Spius Formation.

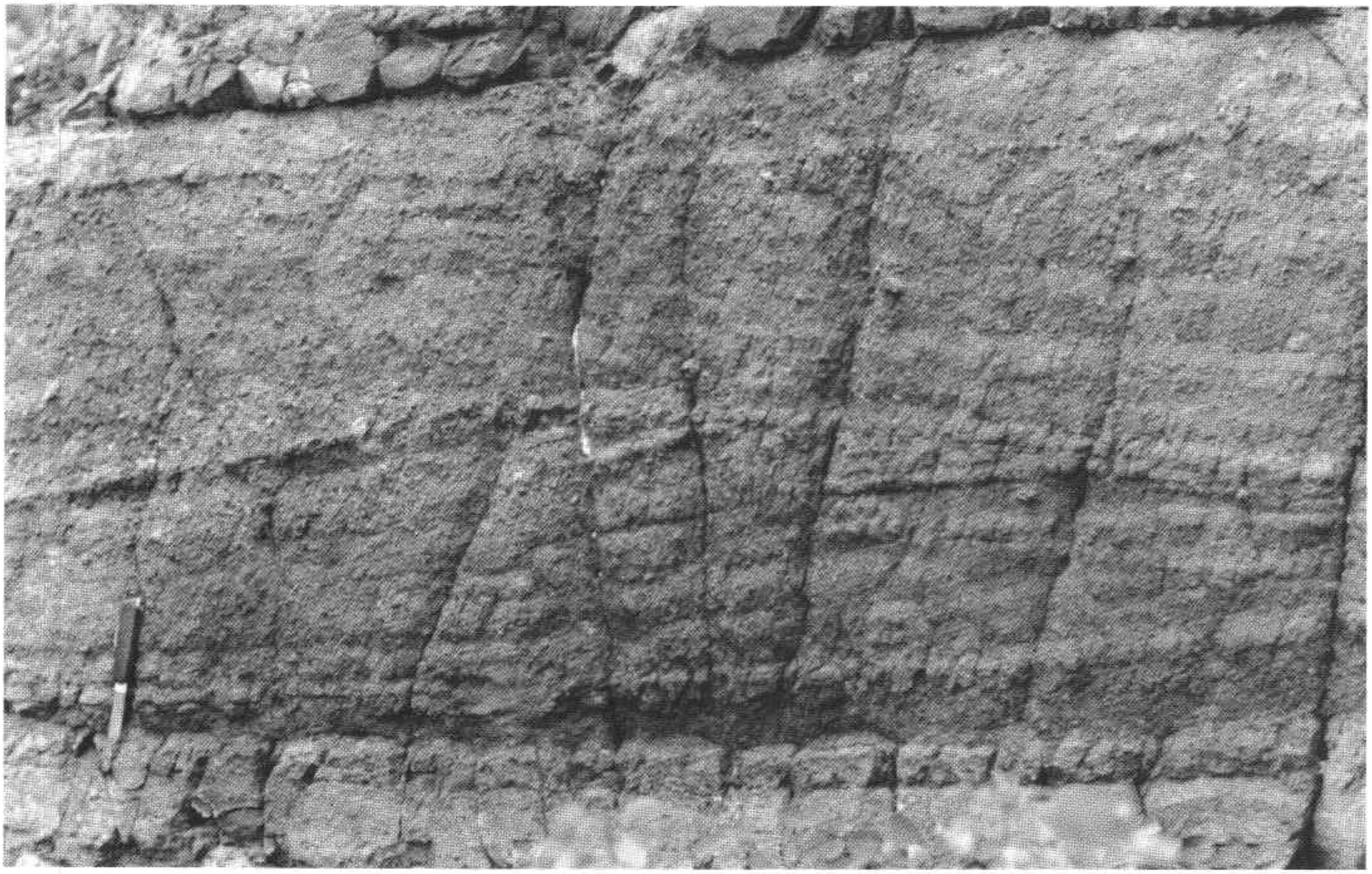


FIG. 6. Dune or antidune in Pimainus lateral-blast or base-surge deposit, 10 km northwest of Kingsvale (open pocketknife in lower left for scale).

Gradational contact between formations

The aforementioned outlier of Spius Formation conformably overlies tuffaceous deposits of the Pimainus Formation. Similarly, Spius Formation flows rest conformably on andesite of the lower formation 0.5 km southeast of the confluence of Spius and Prospect creeks. In both of those areas, Spius Formation lithologies occupy the entire section above the contact with Pimainus Formation. In contrast, 3–4 km southeast of that confluence, the lowest flows of Spius Formation are intercalated with welded and crystal tuffs containing quartz and hornblende. Because those minerals are typical of Pimainus Formation rhyolite but are absent from flows of Spius Formation, the tuffs are identified as part of the lower formation. Therefore, the earliest extrusions of Spius Formation lava were concurrent with the latest emissions of Pimainus Formation. Close temporal relations between these units are corroborated by geochemical arguments made by Thorkelson (1986, 1987), and by palynological age determinations discussed later.

Structure

Cretaceous and Tertiary deformational events affecting the Spences Bridge Group were described by Monger (1985). He suggested that uplift of basement rocks to the west of the Spences Bridge Group was related to downfolding of the volcanic strata into the Nicoamen Syncline, contemporaneous with deposition. This was followed in the Late Cretaceous to early Tertiary by transtensional strike slip and associated normal faulting, giving rise to dextral offset and related minor thrusting on the Yalakom, Hungry Valley, and Fraser faults. Such faulting displaced the northern parts of the Spences Bridge Group farther to the north. Spences Bridge Group rocks east of the Fraser Fault System were greatly affected by transtensional tectonics and subsequent horst and graben formation. Stress orientation and details of this largely Eocene event were given in Ewing (1981), McMechan (1983), Monger (1985), and Thorkelson (1989).

Folding of the Spences Bridge Group into the Nicoamen Syncline, as described by Monger (1985), is generally supported by earlier works describing folding and synclinorium development (Drysdale 1914; Duffell and McTaggart 1952; Jorgensen 1973), but the time of such deformation was not known until fieldwork by Devlin (1981) and Thorkelson (1985). Near Soap Lake, 0.5 km south-southeast of Spences Bridge, Devlin discovered an angular unconformity below which Pimainus Formation rocks are faulted and tilted and above which Spius Formation flows are relatively flat lying. The stratigraphic relations recorded near Kingsvale conflict with those of Devlin (1981) and indicate that, there, the Pimainus and Spius formations share a gradational contact and are, in part, coeval. Monger (1985) noted these differences and accommodated both observations by suggesting that synclinal development was concurrent with eruption of Spences Bridge Group volcanics.

Although the pre-Tertiary form of the Spences Bridge

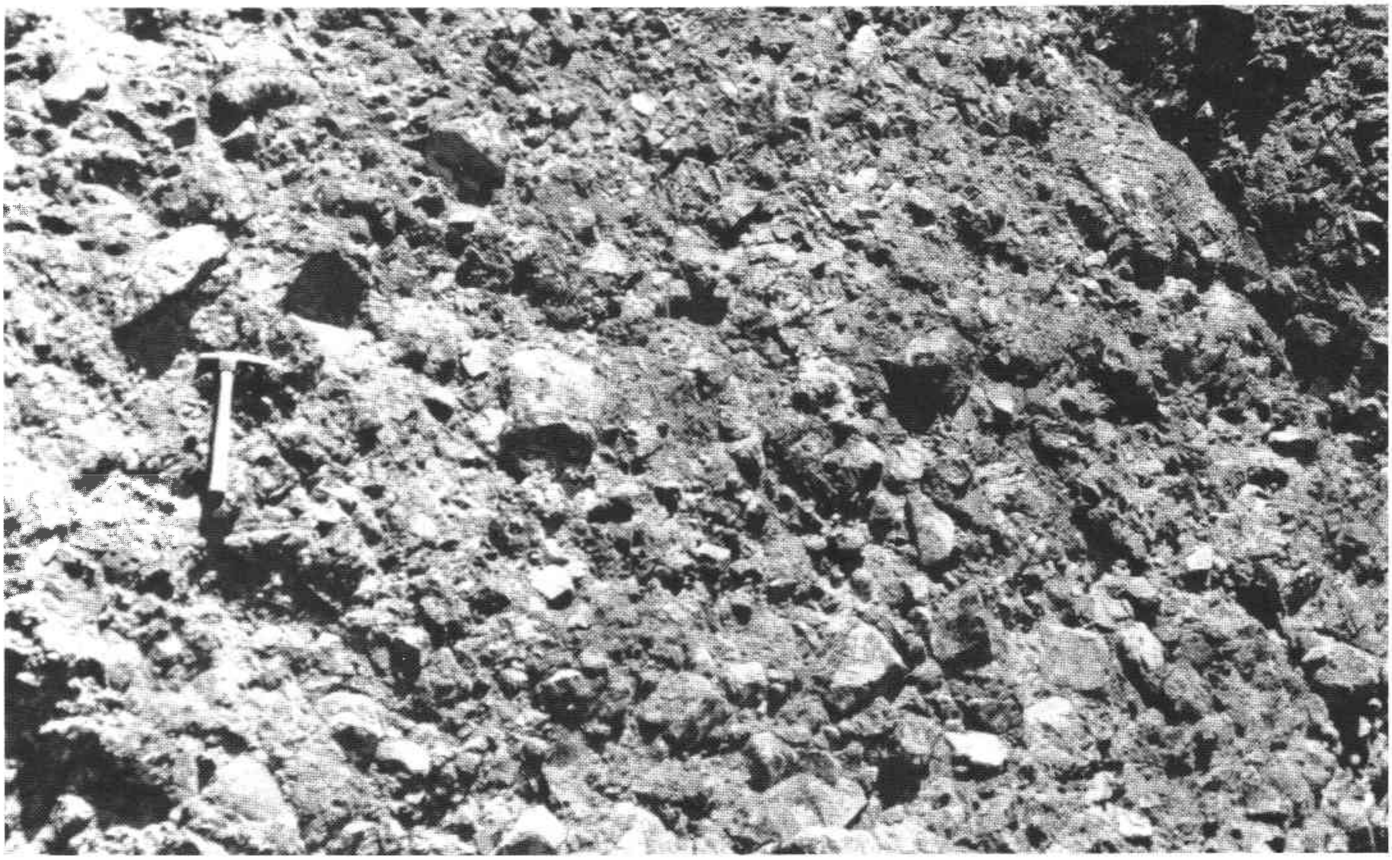


FIG. 7. Cobble breccia in the Gillis Lake fanglomerate. Clasts are mostly greenstone and felsic to intermediate granitoids derived from basement rocks.

Group may have been crudely synclinal, present outcrop patterns and bedding attitudes in the vicinity of Kingsvale are largely controlled by block rotations caused by Paleogene normal faulting (Thorkelson 1986). A lack of simple synclinal form is also evident from bedding attitudes between the Thompson River and the Fraser Fault System (Monger and McMillan 1984) and north of Princeton, adjacent to Highway 5 (Preto 1979). Despite a general consensus of open folding, the north-northwest trend of fold axes described by Duffell and McTaggart (1952) and Monger (1985) is at variance with the findings of Jorgensen (1973), who mapped synclinal and anticlinal folds, with axes trending north-northeast, in Pimainus strata northeast of the Nicola River.

Whatever geometrical form was described by the Spences Bridge Group prior to the Tertiary — perhaps it was a synclinorium complicated by faults and cross-folds, superimposed on stratovolcano morphology — Eocene block faulting may have altered that form so severely that its true shape may be indeterminable. Nevertheless, the Spences Bridge Group is exposed in a linear belt, flanked almost exclusively by the Triassic Nicola Group, the Pennsylvanian to Jurassic Cache Creek Group, and Mesozoic granitoids. This persistent and striking distribution of older and lower level rock units bounding the mid-Cretaceous volcanic sequence, combined with the irregular bedding attitudes of the Spences Bridge Group, leads us to prefer the term "elongate structural depression," recommended by W. H. Mathews (personal communication, 1985) over "syncline," used by Monger (1985). The name "Nicoamen Structural Depression" is therefore proposed here.

Synthesis of physical volcanology

In the vicinity of Kingsvale, deposition of the Pimainus Formation began with extrusion of acid andesite onto a surface of moderate topography underlain by Late Triassic and Early Jurassic volcanic and plutonic rocks. That event was followed by faulting or other tectonic activity, which resulted in deposition of basement-clast fanglomerate. Deposition of various lithologies followed, notably andesite, rhyolite, lahar, and ignimbrite, indicating both extrusive and explosive styles of eruption. The abundance of volcaniclastic rocks and, in places, rhyolite suggests that many of the deposits accumulated on paleoslopes of at least moderate steepness. The absence of pillow lavas and marine fossils and the occasional presence of welded ignimbrite, surge dunes, fluvial sandstone, mudcrack casts in carbonaceous siltstone, and fossilized freshwater clams, plant leaves, and branches indicate that deposition was terrestrial (Drysdale 1914; Devlin 1981).

The composite volcanic stratigraphy of the study area is similar to that described by previous workers in other parts of the Nicoamen Structural Depression (e.g., Duffell and McTaggart 1952; Preto 1979). Rhyolite, which was probably extruded in the form of domes and flows of limited extent, is found throughout the structural depression, suggesting that Pimainus rocks were erupted from several centres and accumulated as a set of contiguous stratovolcanoes. Eruption from multiple vents is corroborated by regional differences in geochemistry (Preto 1979; Smith 1986; Thorkelson 1986).

Near Spences Bridge, Spius Formation rocks were

FIG. 8. Intercalated amygdaloidal andesite and scoriaceous breccia: a section through part of the Spius shield volcano. Exposure forms cliff above Prospect Creek, 0.5 km west of Spius Creek, at south end of Spius Formation type area.

deposited on Pimainus rocks after a period of faulting, folding, and erosion (Devlin 1981; Monger 1982, 1985). Near Kingsvale, however, stratigraphic relations are conformable and gradational, suggesting that deformation may have been localized and possibly restricted to the area near Spences Bridge. An alternative and preferred explanation, which accommodates deformation near Kingsvale (implied by the Gillis Lake fanglomerate) and the regional, synvolcanic downfolding proposed by Monger (1985), is that angular relations between units developed only where deposition was discontinuous for a substantial length of time. The Dot beds, stratigraphically separating a composite sequence of Pimainus strata from flows of Spius Formation southeast of Spences Bridge, may represent such a hiatus in local volcanism. Those beds, comprising coarse and fine-grained fluvial and lacustrine rocks (Devlin 1981) and minor tuff but no lava (Duffell and McTaggart 1952; J. W. H. Monger, personal communication, 1985), suggest that while proximal volcanic activity ceased (followed by erosion and deposition of clastic detritus), distal volcanism yielding the tuffs continued. The source of pyroclastic input to that area could have been located near Kingsvale, where volcanism was apparently uninterrupted and Pimainus rocks interfinger with flows of Spius Formation.

Spius Formation, near Kingsvale, was deposited exclusively on the Pimainus. To the north and northwest, however, that formation rests unconformably on rocks of the Nicola Group and Mount Lytton Plutonic Complex, respectively (Monger and McMillan 1984). There, the Spius apparently accumulated on Pimainus rocks and overlapped onto adjacent basement, parts of which may have been stripped of Pimainus Formation by erosion during depositional hiatus. As indicated by highly amygdaloidal textures, most Spius flows were volatile rich and probably very fluid. This, plus the paucity of intercalated clastic rocks suggests that the Spius formed a sequence with a low profile and gentle angle of deposition. Reddened (oxidized) flows and a lack of pillows imply subaerial deposition. Lava of this formation probably flowed into low-lying areas, then accumulated as a shield volcano.

Age of the Spences Bridge Group

The age of the Spences Bridge Group is discussed using the Decade of North American Geology (DNAG) time scale (Palmer 1983), which gives 113 and 97.5 Ma as the early and late boundaries of the Albian age, respectively.

Isotopic dates

Several isotopic dates from Pimainus Formation and correlative rocks in the belt were previously determined. The first, a 91.6 ± 3 Ma (latest Cenomanian) K–Ar whole-rock date (Church 1975; Church *et al.* 1979), was obtained from lave underlying coal-bearing Tertiary strata, about 24 km northwest of Spences Bridge, near Hat Creek. The second was a 112 ± 10 Ma (2σ) (earliest Albian) Rb–Sr determination from flows about 20 km north of Princeton (Preto 1979), which has since been recalculated in three additional analyses to 104 ± 22 Ma (2σ) (R. L. Armstrong, personal communication, 1986). From the Summers Creek stocks, which intrude those flows, Preto (1979) dated mineral separates yielding one hornblende (96.8 ± 2.6 Ma) and two biotite (98.2 ± 2.6 and 96.7 ± 2.1 Ma; 1σ) dates. These latest Albian to earliest Cenomanian dates constitute a minimum age for the Pimainus Formation in that area. Mathews and Rouse (1984) reported one K–Ar hornblende (96.7 ± 3.4 Ma) and three K–Ar whole-rock (101.0 ± 3, 97.4 ± 3.4, and 90.9 ± 3.2 Ma; 1σ) dates from lavas west of the Fraser Fault System, near the settlement of Gang Ranch, which they correlated with Spences Bridge Group rocks. The oldest date (late Albian) should be regarded as the minimum age of those rocks because of probable and variable Ar loss. Smith (1986) produced a Rb–Sr scatterchron of 115 ± 35 Ma (2σ) from samples he collected from the Nicola River valley.

Five K–Ar whole-rock dates (58.7 ± 2.3, 80.0 ± 3.0, 83.6 ± 3.0, 90.5 ± 3.3, and 94.4 ± 3.4 Ma; 1σ) were obtained by Thorkelson (1985, 1986) for Pimainus lava within a few kilometres of Kingsvale. He regarded that large range in age (mid-Cenomanian to late Paleocene) as being a result of variable Ar loss, especially from poorly retentive mesostasis, resulting from zeolite-grade metamorphism and devitrification. Consequently, even the oldest date was suspected of being younger than the actual age of the Pimainus Formation.

Three K–Ar whole-rock dates on Spius rocks were reported by Thorkelson (1985, 1986). Two of those (93.6 ± 3.4 and 91.7 ± 3.3 Ma) are Cenomanian and the other (79.2 ± 3.1 Ma; 1σ) is Campanian. A fourth K–Ar whole-rock date (82.0 ± 3.2 Ma: Campanian) was obtained by Monger and McMillan (1984) from a dyke cross-cutting Spius flows and thought to be a feeder to that unit (J. W. H. Monger, personal communication, 1984).

Paleobotany and palynology

Previous work

Before 1976, when the first isotopic date on the Pimainus Formation was published (Church 1975), the age of that unit was based on a few collections of fossil leaves. The first collection, made by Drysdale (1914) from the Pimainus Hills, gave an apparent Jura-Cretaceous age, but the samples were later re-examined by Bell (1956), who assigned an Aptian age. Bell (1956) also examined seven other collections from that unit made by Rice (1947) and Duffell (Duffell and McTaggart 1952) from outcrops within the study area. To five of those collections, Bell (1956) assigned Albian ages; to the other two, he gave an Aptian age. Hopkins (1981) identified palynomorphs that he collected from the Gordon Creek locality of Duffell and McTaggart (1952), about 3 km east of Dot. He suggested, based on what he termed "the questionable presence of angiosperm pollen," that Pimainus Formation could be as young as Cenomanian.

Prior to work by the writers, no fossils were collected from Spius Formation. However, Devlin (1981) collected fossil fruit from the overlying Squianny Creek sediments, an informal, coal-bearing unit occupying only 2 km^2, 5 km south of Spences Bridge, to which Rouse (Rouse *in* Devlin 1981) gave a broader Late Cretaceous age.

Recent studies

We examined several collections of plants and palynomorphs from the Pimainus Formation within the study area. One of the palynomorph samples, Dot East, was extracted from rocks located just each of Highway 8, near Dot, and was donated by W. J. McMillan of the British Columbia Ministry of Energy, Mines and Petroleum Resources. Two others, HFA-6 and HFA-7, were collected by W. S. Hopkins, late of the Geological Survey of Canada, Calgary. The resultant slides, kindly forwarded to us by A. R. Sweet of the same office, were the actual samples used by Hopkins (1981), whose results were given earlier. In addition, palynomorphs were recovered from the first demonstratively fossiliferous strata of Spius Formation: dark siltstone outcropping in a roadcut of the Gillis Lake road, immediately west of a gas pipeline cut, 1 km west of Kingsvale.

The species of leaves from four localities within the Pimainus Formation are listed in Table 1, together with notes of their distribution in other rock units in British Columbia as reported by Bell (1956). The palynomorph species, according to the index of Davies (1985), and their distribution in both the Spius and Pimainus formations are shown in Table 2.

The leaf assemblage from the Pimainus Formation is similar to assemblages reported by Bell (1956) from the "Kingsvale Group" (p. 35), the Pasayten Group of southwestern British Columbia (p. 33), and the Commotion Formation of northeastern British Columbia (p. 37). A later and more extensive list of leaves from the Pasayten Group was given by Coates (1974, Table A6, p. 160). These assemblages are dominated by ferns and gymnosperms. Significantly, however, they contain two or more species of angiosperms. Particularly important are leaves of *Menispermites potomacensis* and *Menispermites reniformis*, both of which occur in the Commotion Formation and one of which is present in each of the Pasayten and "Kingsvale" groups. All three assemblages were assigned an Albian age by Bell (1956) and by Coates (1974) for the Pasayten assemblage. Furthermore, Bell (p. 58) tentatively assigned the Commotion assemblage to the late Albian. Support for a late Albian age is also found in the first occurrence of leaves of *M. potomacensis* in the upper Patapsco Formation, assigned a late Albian age by Doyle and Hickey (1976, Fig. 28, pp. 178–179.

A late Albian age of about 100 Ma for the palynoassemblages of both the Spius and Pimainus formations (Table 2) is equally compelling. The most significant feature of the palynoassemblage is the 11 species of angiosperm pollen. As shown definitively by Singh (1971, 1975), the earliest angiosperm pollen, *Tricolpites micromunus*, occurs in the Loon River Formation (middle Albian) of northwestern Alberta. Angiosperm pollen do not become common until the interval consisting of the upper Harmon Member of the Peace River Formation – lower Shaftesbury Formation, which spans the late middle to late Albian age range (Singh 1975, Table 2, p. 375). Six of the 11 angiosperm species from the Spius–Pimainus assemblage occur in this interval. The most definitive pollen is *Psilatricolpites parvulus* (Pl. 1, figs. 7, 8), which first occurs in western Canada in the lower Shaftesbury Formation in the lower Peace River region and is of late Albian age (Singh 1971, Table 6, p. 18; 1975, Pl. III. p. 385). This same species occurs as well in the Upper Shale unit of the central plains (Norris 1967), also of late Albian age. Hence the palynoassemblage supports the leaf evidence for a late Albian assignment for the Pimainus Formation as well as the Spius Formation. The presence in the Spius of *Psilatricolporites prolatus* (Pl. 1, fig. 18), a smooth pollen with incipient pores, attests to a very late Albian age, equivalent to the occurrence

TABLE 1. Distribution of fossil leaf species in Pimainus Formation

Location:	Coquihalla Highway	Kingsvale	MVT84-291	MVT85-24	
Collector:[a]	DJT	GER	DJT	DJT	
Latitude N:	49°54′20″	49°54′14″	49°53′57″	50°14′11″	
Longitude W:	120°54′20″	120°54′48″	120°50′36″	121°06′40″	Other B.C. localities
Ferns					
Coniopteris brevifolia	×				Jackass Mtn. Gp.
Gleichenites nordenskioldi	×				Jackass Mtn. Gp.
Cladophlebis alberta	×	×			Pasayten Gp.; Pimainus Fm.[b]
Cladophlebis strictinervis	×				Bullhead Gp.
Cycadophytes					
Ptilophyllum (Anomozamites) montanense				×	Jackass Mtn. Gp.; Pimainus Fm.[b]
Nilssonia canadensis		×			Pimainus Fm.[b]
Pseudocycas sp. A. cf. *unjiga*		×			Pasayten Gp.; Pimainus Fm.[b]
Coniferophytes					
cf. *Cyparissidium gracile*		×			Pasayten Gp.; Pimainus Fm.[b]
cf. *Sesquoia condita*		×			Pimainus Fm.[b]
Elatocladus smittiana		×			Jackass Mtn. Gp.
Pteridosperm					
Sagenopteris elliptica	×				Pasayten Gp.
Angiosperms					
Menispermites potomacensis	×				Pimainus Fm.[b]
Menispermites reniformis			×		Pasayten Gp.

[a]GER, G. E. Rouse; DJT, D. J. Thorkelson.
[b]Other Pimainus Formation localities described in Bell (1956) and other publications under Kingsvale Group or Spences Bridge Group.

of the first smooth tricolporate pollen in the upper part of the lower Shaftesbury Formation of northwestern Alberta, as pointed out by Singh (1975, Table 11, p. 375). In addition, the occurrence of *Bacumonoporites baculatus* and *Rugumonoporites convolutus*, which were reported from the Cenomanian by Pierce (1961), indicates that Spius Formation was laid down just prior to that time, i.e., in the latest Albian.

Because rocks hosting the samples collected by Hopkins were previously thought to be Aptian (Bell 1956) but are herein identified as late Albian, the other two collections called "Aptian" by Bell (1956) may also be of late Albian age. Apparently, Bell assigned an Albian or Aptian age to his Early Cretaceous collections based on angiosperm presence or absence, respectively. The absence of angiosperm leaves, however, may be the result of insufficient sampling or a local fern-cycadophyte–gymnosperm-dominated assemblage that also occurs in Albian leaf assemblages in other areas of western North America. We anticipate that future work on the other "Aptian" sites will reveal Albian angiosperm leaves or pollen.

A late Albian age is supported by Preto's (1979) latest Albian to earliest Cenomanian K–Ar ages of granitic plutons that intrude Pimainus rocks north of Princeton, by his Albian Rb–Sr isochron, and by Mathews and Rouse's (1984) late Albian K–Ar dates from correlatives of Pimainus Formation west of the Fraser Fault System. Other K–Ar determinations by Mathews and Rouse (1984), Church (1975), Monger and McMillan (1984), and Thorkelson (1985, 1986) yielding Cenomanian and younger ages for the Spius and Pimainus formations are not supported by fossil evidence and are almost certainly less than the actual age.

Conclusions

Mid-Cretaceous volcanic rocks in southwestern British Columbia east of the Fraser Fault System, are exposed in a long, linear belt flanked primarily by older plutonic, volcanic and sedimentary rocks. The Cretaceous section consists of two main divisions: (1) a lower, composite sequence comprising basaltic to rhyolitic lavas and a variety of pyroclastic and epiclastic rocks, overlain by (2) a succession of mostly amygdaloidal andesite flows. Both units were deposited subaerially and metamorphosed to zeolite grades.

Previous workers used the names "Spences Bridge Group" and "Kingsvale Group" for various parts of the volcanic pile. We propose revision of lithostratigraphic nomenclature because (*i*) the strata originally described by Rice (1947) as Kingsvale Group are herein regarded as part of the Spences Bridge Group as defined by Drysdale (1914) and (*ii*) inconsistent application of names by subsequent authors has resulted in a confusing array of nomenclature.

We recommend that the term Kingsvale Group be abandoned and that the Spences Bridge Group be expanded to include all mid-Cretaceous volcanic and related sedimentary rocks in the belt. We also suggest that the lower, composite unit be named "Pimainus Formation" and that the upper sequence of amygdaloidal andesite be named "Spius Formation." We anticipate that additional work will result in identification of specific units as members. Paleogeographic reconstructions suggest that mid-Cretaceous rocks west of the Fraser Fault System, north of the Hungry Valley Fault, are probably correlative with Pimainus Formation. Cretaceous strata southwest of the Yalakom Fault do not belong to the Spences Bridge Group.

The Pimainus Formation and its correlatives comprise terrestrial volanic, fluvial, and lacustrine rocks that overlap the Cache Creek, Quesnel and Stikine terranes of terrane I (Monger 1984). Deposition, which began on a surface of moderate topography, was accompanied by faulting and open folding. The multiple-vent, stratovolcano morphology of the

TABLE 2. Distribution of palynomorph species in Spius and Pimainus formations

Formation:	Spius	Pimainus				
Location name:	Gillis Road	MVT84-291	HFA-6	HFA-7	DOT east	
Collector:[a]	GER/DJT	DJT	WSH	WSH	WJM	
Latitude N:	49°54′30″	49°53′37″	[b]	50°15′	50°13′	
Longitude W:	120°55′30″	120°50′36″	[b]	121°02′	121°05′	Figure No. in Pl. 1
Fern spores						
Nodosisporites spinosus					×	
Plicatella problematicus				×		1, 5
Biretisporites potoniaei	×	×	×	×	×	
Corniculatisporites auritus					×	
Cicatricosisporites australiensis				×	×	6
Concavissimisporites minor			×			
Concavissimisporites punctatus					×	4
Cyathidites minor	×		×	×		
Deltoidospora diaphana	×	×	×		×	
Deltoidospora rhytisma		×				
Distaltriangulisporites irregularis	×			×		2
Distaltriangulisporites perplexus				×	×	3
Distaltriangulisporites mutabilis					×	
Foveosporites labiosus			×	×	×	
Foveosporites canalis				×	×	
Gleicheniidites senonicus		×	×	×	×	
Laevigatosporites ovatus	×	×	×	×	×	
Matonisporites crassiangulatus	×				×	
Microreticulatisporites uniformis				×		
Osmundacidites wellmanii		×				
Polypodiisporites cenomanianus		×				
Reticulisporites elongatus					×	
Triplanosporites sp.	×	×				
Gymnosperm pollen						
Alisporites bilateralis		×	×	×	×	
Araucariacites australis		×				
Cedripites cretaceous			×		×	
Cedripites canadensis		×			×	
Cerebropollenites mesozoicus		×	×	×	×	
Cycadopites follicularis	×	×		×		
Eucommiidites minor		×	×	×		
Pinuspollenites labdacus	×					
Pinuspollenites granulatus					×	
Vitreisporites pallidus	×		×	×		
Angiosperm pollen						
Clavatipollenites hughesii			×	×	×	11
Clavatipollenites minutus			×			12
Clavatipollenites tenellis	×	×				
Psilatricolporites parvulus			×	×		7, 8
Psilatricolporites prolatus	×					18
Retitricolpites minutus			×			16
Retitricolpites sphaeroides	×					17
Tricolpites crassimurus		×	×	×		9, 10
Tricolpites micromunus	×		×	×		
Tricolplites minutus	×		×	×		
Tricolpites cf. *pachyexinus*		×				15
Uncertain affiliation						
Bacumonoporites baculatus	×					
Inapertisporites sp.	×					
Inaperturopollenites parvoglobulus		×				
Monocolpites sp.		×				13
Monosulcites chaloneri	×					19
Rugumonoporites convolutus	×					
Verrutricolpites sp.		×				14
Ovoidites sp.	×					
Other apparent algal cysts	×	×				

[a]GER, G. E. Rouse; DJT, D. J. Thorkelson; WSH, W. S. Hopkins; WJM, W. J. McMillan.
[b]Unspecified location, near HFA-7.

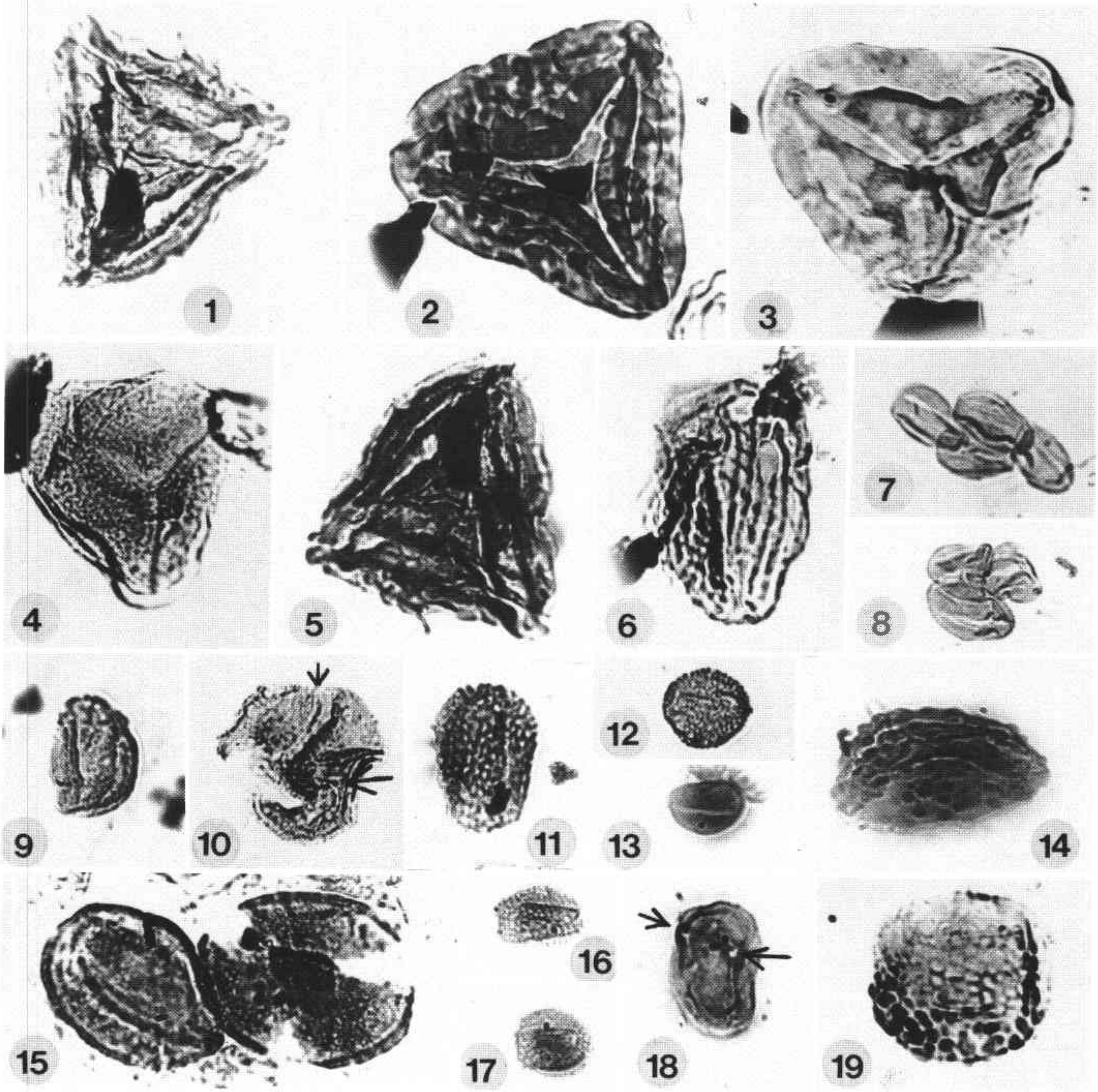


PLATE 1

Representative palynomorphs of the Spius and Pimainus formations of the Spences Bridge Group in south-central British Columbia. All figures ×1000.

FIGS. 1, 5. *Plicatella problematica* Burger.

FIG. 2. *Distaltriangulisporites irregularis* Singh.

FIG. 3. *Distaltriangulisporites perplexus* (Singh) Singh.

FIG. 4. *Concavissimisporites punctatus* (Delcourt and Sprumont) Brenner.

FIG. 6. *Cicatricosisporites australiensis* (Cookson) Potonie.

FIGS. 7, 8. *Psilatricolpites parvulus* (Groot and Penny) Norris.

FIGS. 9, 10. *Tricolpites crassimurus* (Groot and Penny) Singh: (9) equatorial view; (10) polar view: arrows indicate position of two colpi; the third would have been along the ripped surface at the lower left.

FIG. 11. *Clavatipollenites hughesii* Couper.

FIG. 12. *Clavatipollenites minutus* Brenner.

FIG. 13. *Monocolpites* sp.

FIG. 14. *Verrutricolpites* sp.

FIG. 15. *Tricolpites* cf. *pachyexinus* Couper: left-hand specimen: equatorial view; right-hand specimen: polar view.

FIG. 16. *Retitricolpites minutus* Pierce.

FIG. 17. *Retitricolpites sphaeroides* Pierce.

FIG. 18. *Psilatricolporites prolatus* Pierce.

FIG. 19. *Monosulcites chaloneri* Brenner.

Pimainus was superposed, in part, by vesicular, andesitic flows of Spius Formation, which accumulated as a shield volcano. At the present northern limit of Spius distribution, where cessation of Pimainus volcanism was succeeded by deformation during a hiatus prior to overlap by Spius lavas, angular relations developed. Conversely, near Kingsvale, volcanism was apparently uninterrupted and Pimainus rocks were overlain conformably to gradationally by the Spius. Cretaceous stratigraphic and structural relations were overprinted by Tertiary block faulting. Because of this complex structural history, compounded by a paucity of recognizable stratigraphic continuity, we recommend the nonspecific term "Nicoamen Structural Depression" for the elongate pattern of Spences Bridge Group distribution.

The age of the Spences Bridge Group was estimated previously by several workers on the basis of fossil leaves, palynomorphs, and isotopic dating. Estimations ranged from Aptian to Cenomanian and younger. Our recent identification and analysis of fossil leaves and palynomorphs, from both new and previously collected specimens, provide a more precise determination. The presence of two angiosperm leaves and 10 angiosperm pollen point to a late Albian age, with three palynomorphs indicating that the Spius Formation was likely deposited just prior to the Cenomanian. Hence there seems to be no significant time break within the Spences Bridge Group. We anticipate that similar rocks west of the Fraser Fault System, northeast of the Hungry Valley Fault, will prove correlative to the Spences Bridge Group, thus extending the distribution of this mid-Cretaceous unit in southwestern British Columbia.

NOTE ADDED IN PROOF: A recent U–Pb isotopic analysis of zircon from rhyolite of the Pimainus Formation yielded a date of 104.5 ± 0.3 Ma from duplicate concordant analyses (Irving and Thorkelson, in preparation). This date, courteously provided by R. R. Parrish of the Geological Survey of Canada, is in excellent agreement with our palynological and leaf determinations.

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