

Structural style and stratigraphy of southwest Spatsizi map area, British Columbia¹

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Abstract

Western Spatsizi map area is underlain by Lower to Middle Jurassic Hazelton Group, Lower to Middle Jurassic Spatsizi Group, and Middle Jurassic to Cretaceous(?) Bowser Lake Group. Most of the area is underlain by the Bowser Lake Group, which consists of sequences of clastic sedimentary rock similar to those mapped to the east, including Ashman Formation at the base, and associated turbidites. Shallow marine strata with abundant conglomerate and coarsening-up sequences (some with coal), and nonmarine sequences are also present.

The style and intensity of folds resemble those in eastern Spatsizi map area; however, the variations in axial surface trends and the interference of folds contrast with the dominant northwest trends and rare interference of folds observed to the east. Folded Bowser Lake Group is overlain by Pliocene columnar basalt flows, informally called the Maitland volcanics.

Résumé

Le sous-sol de la région levée de Spatsizi ouest est constitué du groupe de Hazelton datant du Jurassique inférieur à moyen, du groupe de Spatsizi datant du Jurassique inférieur à moyen et du groupe de Bowser Lake datant du Jurassique moyen au Crétacé (?). Le sous-sol de la majeure partie de la région est constitué du groupe de Bowser Lake qui consiste en séries de roches sédimentaires détritiques similaires à celles qui ont été cartographiées à l'est; il comprend la formation d'Ashman à sa base et des turbidites associées. Des couches marines peu profondes sont accompagnées d'abondantes séries de conglomérats et à grand classement inverse (certaines accompagnées de charbon) de séries non marines.

Le style et l'intensité des plis ressemblent à ceux qu'on trouve dans la région levée de Spatsizi est. Toutefois, les variations des directions axiales superficielles et interférence des plis contraste avec les directions prédominantes nord-ouest et les rares interférences des plis observées à l'est. Le groupe plissé de Bowser Lake est recouvert de coulées de basalte prismatique, connu sous le nom plus familier de roches volcaniques de Maitland.

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INTRODUCTION

This work is part of a long-term project designed to understand the depositional, structural, and thermal history of the northern Bowser Basin. Results of the first four seasons of field work, and reviews of the regional geology were given by Evenchick (1986, 1987, 1988, 1989). The most recent regional map was published by Gabrielse and Tipper (1984).

The Bowser Basin occupies 50 000 km² of north-central British Columbia (Fig. 1). The Jurassic and Lower Cretaceous marine and nonmarine clastic sedimentary fill of the basin is called the Bowser Lake Group (Tipper and Richards, 1976). The basin is bounded on the west and north by island arc volcanics of the Lower to Middle Jurassic Hazelton Group, and on the east by nonmarine sedimentary rock of the Cretaceous Sustut Group (Fig. 1). The Spatsizi Group is a thin but regionally mappable unit between the Bowser Lake and Hazelton groups. Strata of the Hazelton, Spatsizi, Bowser Lake, and Sustut groups are intensely folded and faulted, resulting in structural contacts between the Bowser Basin and its bounding units. Deformation occurred in latest Jurassic(?) to latest Cretaceous time, forming a fold belt more than 200 km across strike, with northeasterly shortening locally up to 50% (Evenchick, 1988, 1989).

Geological mapping in the summer of 1989 concentrated on the area between the Little Klappan River and the south and west boundaries of Spatsizi map area (Fig. 1). The Bowser Lake Group occupies much of the area, and in the

north is in stratigraphic contact with the underlying Spatsizi Group. The Bowser Lake Group here includes turbidites, nonmarine strata, and shallow marine clastic sedimentary rock, some with intercalated coal seams. The style, orientation, and scale of folding of Bowser Lake Group vary remarkably. Folded Bowser Lake Group is overlain by erosional remnants of basaltic flows of Early Pliocene age informally called the Maitland volcanics (Souther, in press).

As of April 1989, the project is funded by the Frontier Geoscience Program, an Energy Mines and Resources initiative to understand the geological evolution of sedimentary basins. Specifically, the objectives are (1) to gain controls on the deep geological structure, (2) to elucidate the internal geology and evolution of basins, (3) to understand processes governing the generation, accumulation, and preservation of hydrocarbons, and (4) to identify hazards and constraints to development. In the case of the Bowser Basin project, the mandate is to continue developing a regional structural and stratigraphic framework for the northern Bowser Basin, and to collect, interpret, and present data pertaining to the thermal maturation of the northern part of the basin. Other contributions associated with this project are those of Cookenboo and Bustin (1990), and Ricketts (1990).

STRATIGRAPHY

Figure 2 shows the distribution of the four regional stratigraphic units: the Hazelton, Spatsizi, and Bowser Lake

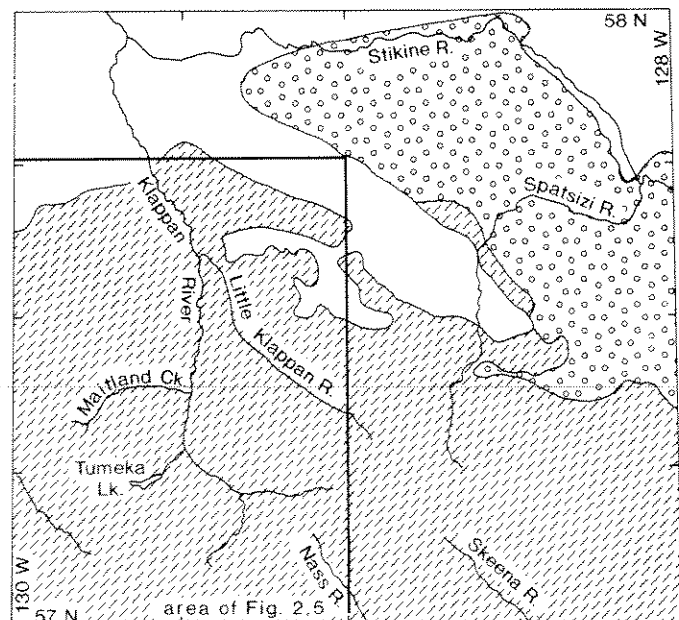
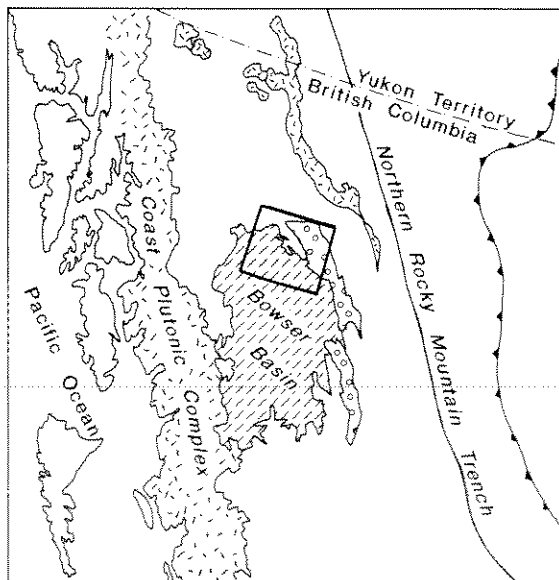


Figure 1. Location of the Bowser Basin and Spatsizi map area (left), and regional geological and geographic features in Spatsizi map area (right). The location of Figures 2 and 5 is outlined.

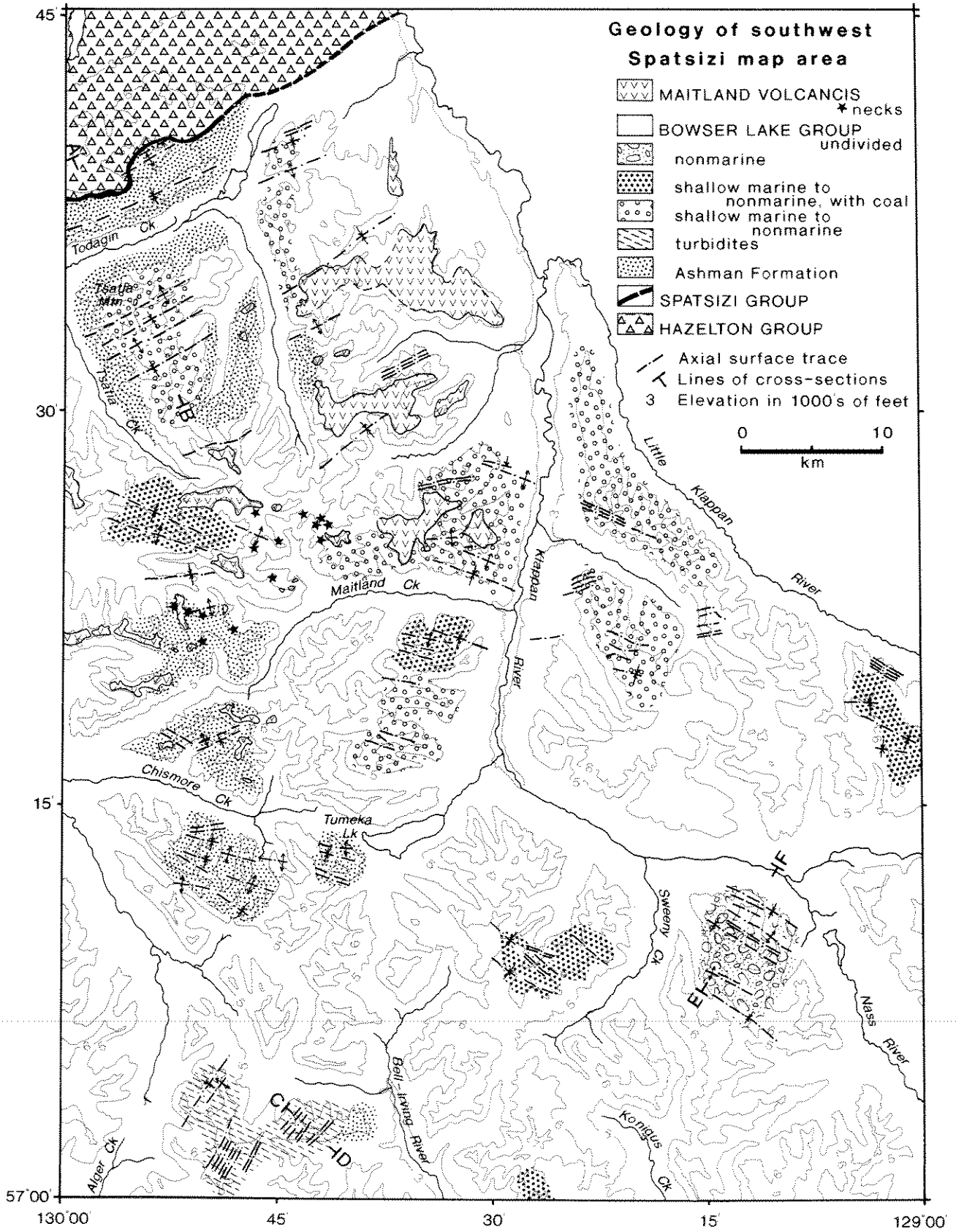


Figure 2. Generalized geological map of the study area, showing main stratigraphic units, facies in the Bowser Lake Group, axial surface traces of major folds, and location of cross-sections in Figure 6.

groups, and the Maitland volcanics. The Bowser Lake Group is divided into five units, of which four are not conventional rock-stratigraphic units. The fifth, the Ashman Formation, is a regionally mappable unit that is defined for the southern Bowser Basin (Tipper and Richards, 1976). The others are units grouped on the basis of common lithologies, sequences, sedimentary structures, and fossils. These characteristics reflect the general environment of deposition. Although they are presumed to evolve from marine to nonmarine in a general regression, there is no place where a complete section can be observed. Areas with good exposure of several hundred metres of section are separated by complex structures or by large, drift-covered valleys with unknown structure. As a result, the stratigraphic relationships of neighbouring areas are unknown, and the map of the Bowser Lake Group is a generalized facies map.

Hazelton Group

Lower and Middle Jurassic volcanic rock surrounding large parts of the Bowser Basin are called the Hazelton Group, a term redefined by Tipper and Richards (1976) for strata south and southeast of the Bowser Basin. In Spatsizi map area, volcanics of the Hazelton Group are referred to informally as the Cold Fish volcanics (Thomson et al., 1986; Evenchick, 1986) and comprise a subaerial to shallow-marine bimodal suite (Thorkelson, 1988). Most rocks are Early Pliensbachian (Early Jurassic) in age, but volcanics of Toarcian (late Early Jurassic) and Bajocian (early Middle Jurassic) age are also present (Smith et al., 1984).

In western Spatsizi map area the volcanics were examined where they are in contact with the Spatsizi Group (Fig. 2). Lithologies near the contact include basalt, rhyolite, tuff, breccia, volcanogenic sandstone, and conglomerate. These strata are included in the area mapped as Bajocian volcanics by Smith et al. (1984).

Spatsizi Group

The Spatsizi Group was established by Thomson et al. (1986) for marine clastic sedimentary rock in central Spatsizi map area that range in age from Early Jurassic to early Middle Jurassic. It is thought to be a basinal facies equivalent of the Hazelton Group (Smith et al. 1984; Thomson et al. 1986).

Reconnaissance mapping by Gabrielse and Tipper (1984) showed Bowser Lake Group north of Todagin Creek to be mainly in fault contact with volcanic rocks of the Hazelton Group. The local stratigraphic contact between the two units implied that the Spatsizi Group is absent. Mapping this season revealed a semi-continuous outcrop belt of Spatsizi Group between the underlying volcanics and the overlying Bowser Lake Group (Fig. 2). Contacts with underlying and overlying units are commonly covered by overburden; they are assumed to be stratigraphic because all map units are represented. The contact between the Spatsizi Group and Bowser Lake Group was seen in one locality. There, siltstone and chert-pebble conglomerate of the Bowser Lake Group are underlain by 3 m of fine and medium grained sandstone and, lower still, by siliceous, varicoloured siltstone of the Spatsizi Group. The siltstone is assigned to the

Quock Formation of the Spatsizi Group because of strong lithological similarity. The apparent thickness of the Spatsizi Group ranges from about 40-100 m. Thrust faults and duplexes structurally thicken the section to account for the higher figure, which is far less than the maximum thickness of 730 m at the type locality in central Spatsizi map area. No minimum thickness was given by Thomson et al. (1986).

Bowser Lake Group

The Bowser Lake Group is divided into five lithological units (Fig. 2). These are described below in order of marine to nonmarine, with no stratigraphic order implied. The Ashman Formation has been mapped at the base of the Bowser Lake Group elsewhere (Tipper and Richards, 1976; Gabrielse and Tipper, 1984). The other four units are facies that probably overlap in time and may repeat in a vertical section.

Ashman Formation

The Ashman Formation is the lowest mappable unit of the Bowser Lake Group and overlies the Spatsizi Group at many localities in central Spatsizi map area (Gabrielse and Tipper, 1984). It consists of a thick section of black-weathering siltstone and very fine grained sandstone. Lenses and laterally continuous sheets of conglomerate are also present. The thick, dominantly dark, recessive-weathering, fine grained clastics, are assigned to the Ashman Formation on the basis of stratigraphic position above the Spatsizi Group and lithological similarity to Ashman Formation to the east (Gabrielse and Tipper, 1984; Evenchick, 1987). The section north of Todagin Creek directly overlies the Spatsizi Group and is at least 1400 m thick. Ashman Formation also occurs south of Todagin Creek on the lower flanks of Tsatia Mountain and the surrounding ridges. Thick sections of black siltstone with minor sandstone and conglomerate north and south of Chismore Creek are correlated with Ashman Formation (Fig. 2) on the basis of lithological similarity. Ashman Formation in central Spatsizi map area is Late Bathonian to Early Oxfordian in age (Gabrielse and Tipper, 1984), but the upper and lower age limits in the area studied are unknown.

Turbidites

The southwest corner of the map area is underlain by intervals 3-30 m thick dominated by recessive, black-weathering siltstone to very fine grained sandstone, and by resistant, grey weathering, fine to medium grained sandstone (Fig. 3). Sedimentary structures in the fine grained members are parallel lamination, graded bedding, and soft sediment folds. Sedimentary structures in the medium grained members are parallel lamination, massive beds, tool marks, and flute casts; beds vary from 1 cm to 2 m thick. Within each member, the proportion and thickness of beds of the less dominant lithology increases up, and in some intervals, decreases up.

The abundance of graded bedding, the common presence of sole marks on the bottom of massive, medium grained sandstone beds, and the monotonous, rhythmic repetition of

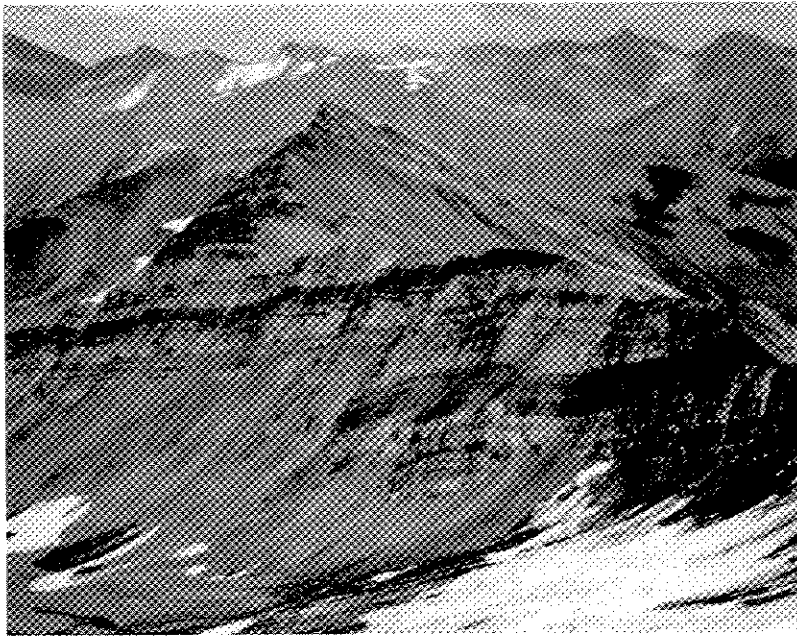


Figure 3. View east of turbidites west of Bell-Irving River. Note the repetition of large- and small-scale resistant sandstone (grey) and recessive siltstone (black) members.

siltstone and sandstone suggest that the rocks are turbidites (Walker, 1984) that were deposited in lobes on the mid and lower fan. The thinning and thickening-up sequences presumably reflect the migration of lobes.

West of Bell-Irving River, at least 1400 m of turbidites are overlain by more than 500 m of black siltstone with conglomerate lenses and sheets that are inferred to be channels feeding distal lobes. The change from turbidite to black siltstone with channels of conglomerate is interpreted to be the result of progradation of slope and inner fan facies above the distal mid and outer fan facies. The part of the section with lenses of conglomerate in thick black siltstone bears many similarities to the Ashman Formation, and is shown as Ashman Formation in Figure 2.

Shallow marine to nonmarine clastic rock (locally coal-bearing)

Most areas shown in Figure 2 as shallow-marine to nonmarine are isolated areas of unknown stratigraphic position relative to other areas. Only between Todagin Creek and the head of Tsatia Creek can this facies be related to other map units. This region needs more study.

On Tsatia Mountain the Ashman Formation is overlain by more than 300 m of fine and medium grained green sandstone with abundant marine fossils. Discrete lenses of conglomerate occur near the upper part of the section. The section dominated by medium grained sandstone is overlain by at least 200 m of rusty-weathering chert-pebble to cobble conglomerate members 10-30 m thick, interbedded with thinner members of fine and medium grained dark sandstone, and rare sandy limestone. The dark intervals contain pelecypods and ammonites, attesting to marine deposition for at least part of the uppermost section. Details of the stratigraphy and sedimentology are given by Ricketts (1990).

A wide range in bed thickness and in the proportion of fine grained clastic sediment to coarse grained clastic sediment characterizes the areas south of Tsatia Creek, north and south of Maitland Creek, and east of Klappan River. Typical sections include: 10-30 m thick coarsening-up cycles with coal and/or carbonaceous siltstone at the base and chert-pebble conglomerate at the top, similar sections with less conspicuous cycles, less conglomerate and no coal, and thick sections of fine and medium grained sandstone (with massive bedding or parallel lamination) and rare coal.

Local coal seams indicate a nonmarine environment. The overlying and underlying strata, however, contain pelecypod coquinas and, less commonly, ammonites, indicating fluctuations between marine and nonmarine conditions.

Nonmarine clastic rock

At least 500 m of section east of Sweeny Creek is dominated by sequences that fine upward from conglomerate (not everywhere present), through massive sandstone, platy sandstone with interbeds of siltstone, thin bedded sandstone and siltstone, dark green sandstone and siltstone, into carbonaceous siltstone with abundant plants and locally coal. The fining up sequences, abundance of delicate plant fossils, and absence of marine fossils suggest a nonmarine, fluvial environment.

Maitland volcanics

The Maitland volcanics are a suite of Early Pliocene flat-lying basalt flows that occur as erosional remnants on the tops of plateaus and peaks between Tsatia Creek and Chismore Creek (Fig. 2, 4; Souther, in press). The remnants consist of laterally continuous sheets of columnar basalt 3-30 m thick. The maximum thickness of a section of flows is 350 m. The upper erosion surface of the flows forms a

plateau at 1960-2260 m (6500-7500 ft) elevation. The lower surface of the flows follows a pre-Pliocene peneplain at 1960-2110 m (6500-7000 ft) on the west, dropping to as low as 1510 m (5000 ft) and lower at the northeast-most occurrences shown in Figure 2. Relief on the lower contact of the flows is minor in most places, but locally is as much as 300 m in 2 km. (Fig. 8). Basalt necks, which rise as much as 200 m above the surrounding topography (Fig. 4), are assumed to be the feeders; they are 100-400 m across the long axis of their oval or circular plan. Fourteen feeders are clustered in a small area northwest of Maitland Creek.

Discussion of stratigraphy

Although little fossil control is available, some generalizations about the stratigraphy of the Bowser Lake Group can be drawn from local relationships. In the north, the Spatsizi Group is overlain by about 1400 m of Ashman Formation, which is in turn overlain by more than 500 m of shallower marine to nonmarine strata. On Tsatia Mountain, the first strata with abundant coal above the Ashman Formation are probably within 500 m of the top of the section on Tsatia Mountain, or in part overlap it. In the south, typical Ashman Formation overlies turbidites at least 1400 m thick that are absent in the north. The combined thickness of turbidites and Ashman Formation is 1900 m, and probably much greater, because the thickness of strata between these beds and the base of the Bowser Lake Group is unknown, as is the thickness between the top of these beds and the first shallow marine or coal-bearing strata. Although estimates of thickness are approximate, the thickness of turbidites and Ashman Formation in the south is probably greater than the thickness of Ashman Formation and overlying strata to the first coal-bearing beds in the north. Biostratigraphic control is needed to refine the stratigraphic position of all units, including the nonmarine strata east of Sweeny Creek, that could be either younger, older, or the same age as shallow marine strata to the west and northwest.

The units described by Cookenboo and Bustin (1989) were not recognized in the study area. Some sections in west Spatsizi area probably represent similar depositional environments to the units outlined by Cookenboo and Bustin (1989), but their stratigraphic position is unknown. As in areas to the east, intense folding and poor biostratigraphic control inhibit recognition of a truly regional stratigraphy.

STRUCTURAL STYLE

The style and orientation of folds on the west side of Spatsizi map area are diverse. Some complexities of the structure are described here. Figure 5 is a summary of stereonet for the regions studied. Each net is centred on the area it represents, and the diameter is roughly the across-strike distance of the area. Regions of relatively simple, cylindrical folding are illustrated by stereonet in which poles to bedding define a great-circle girdle. Areas of more complicated folding, resulting from either superposed folding or noncylindrical folding, are illustrated by a less systematic spread of poles to bedding. Three regions of 'simple' folding, each with a different style and orientation surround a central area of complex folding. In the north, strata are gently folded about northeast and northwest trending axes; northeast axes predominate and the plunge is gentle (Fig. 6, section AB). In the south, between Alger Creek and Bell-Irving River, strata are also folded about northeast-trending, gently plunging axes. In contrast to structures in the north, these are open to tight folds which have accommodated more than 40% shortening (Fig. 6, section CD). East of Alger Creek folds verge to the east, and west of Bell-Irving River they verge to the northwest. The change in vergence suggests a structural culmination between the two areas. East and west of Sweeny Creek and north of Nass River, northwest axial surface trends so common in the rest of Spatsizi map area (Evenchick, 1988, 1989) dominate. East of Sweeny Creek, folds are upright or northeast-verging, and open to close (Fig. 6, section EF). West of Sweeny Creek they are large scale, upright or southwest-verging chevron folds (Fig. 7).

Figure 4. View east to flows and necks of the Maitland volcanics west of Maitland Creek. Three necks are marked by the letter 'N'. The ridge between the two closest necks is capped by flows of columnar basalt.



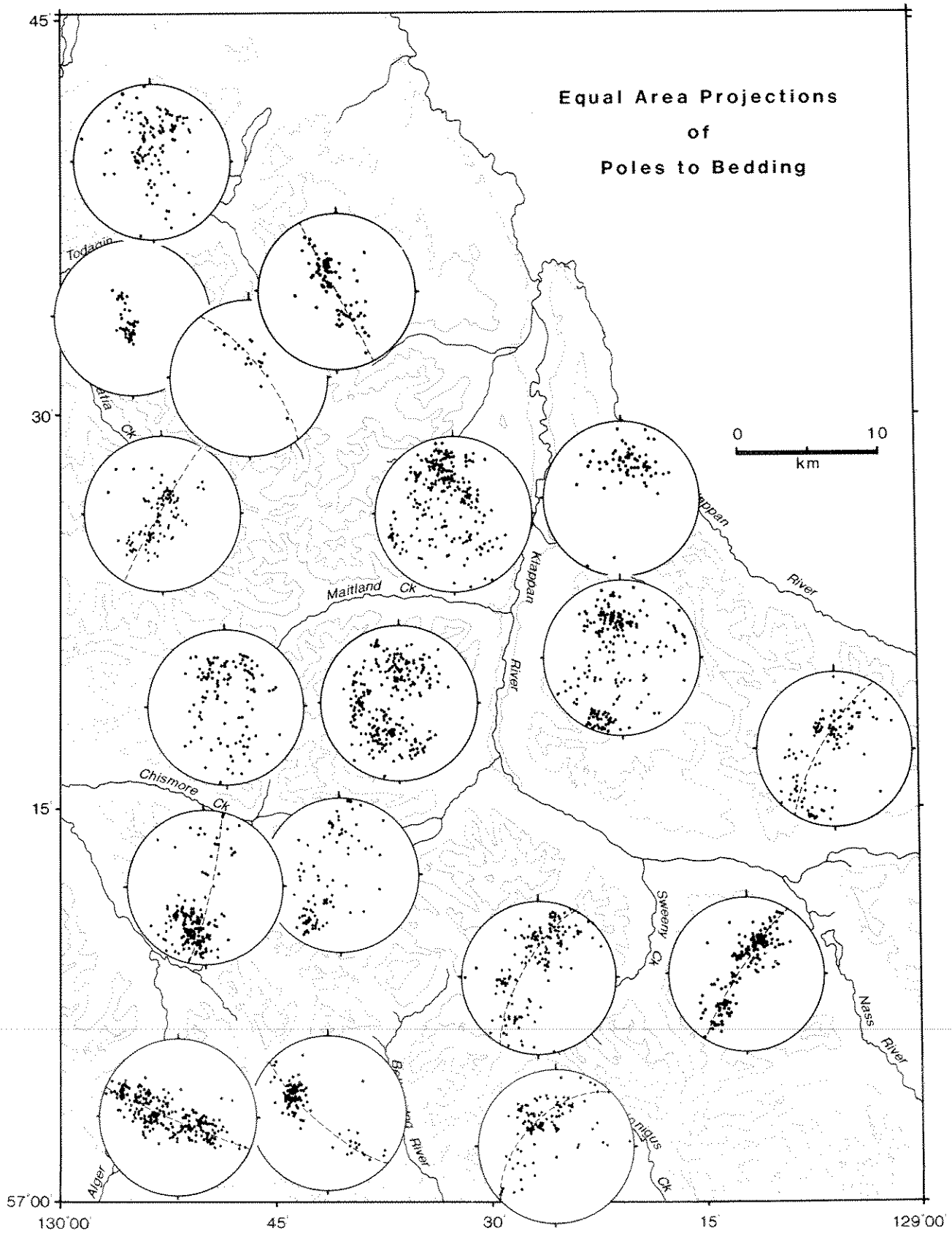


Figure 5. Map of study area with lower hemisphere, equal area projections of poles to bedding. Note the contrast of regions with poles to bedding falling on or near great circles. Regions in the centre of the map have an unsystematic scatter of poles to bedding.

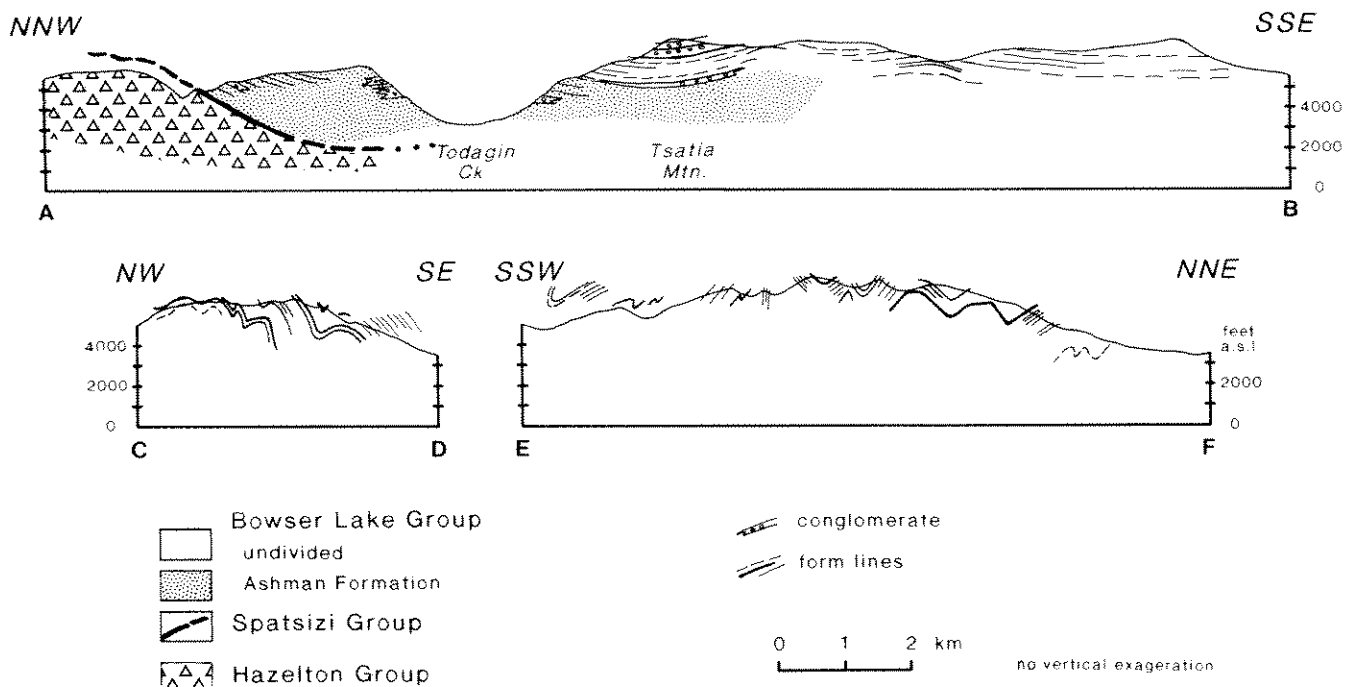


Figure 6. Representative structural cross-sections of three areas of roughly cylindrical folding. Location of the sections shown in Figure 2.

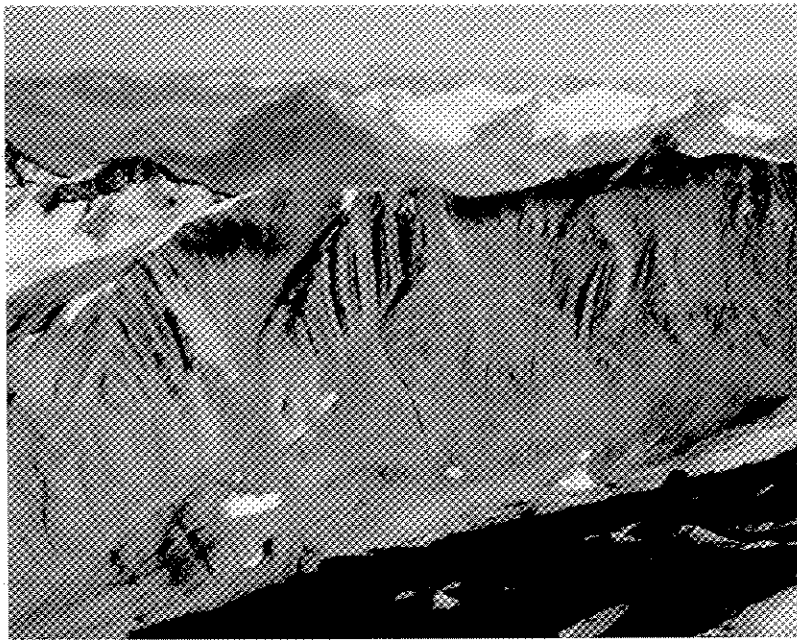


Figure 7. View southeast to large scale chevron folds west of Sweeney Creek.

The regions of differently oriented, but relatively simple folds surround an area (middle of Fig. 5) of complex fold patterns resulting in a wide scatter of poles to bedding, on the scale of this analysis. Closer examination of one area (Fig. 8) illustrates that it can be broken into three domains of cylindrical folding, but one net remains as a scatter of poles in this more detailed analysis. In this example the domains consist of small-scale tight folds that are cylindrical within the domain, but the trend and plunge vary between domains. It is not clear that the different fold trends interfere

with each other; large-scale noncylindrical folding may be the cause of the different fold orientations. In many areas of open to close folding, interference of folds can be observed in the field. For these areas it is clear that a poorly defined great circle is caused by the interference of folds. The relative tightness of the two fold trends determines whether poles fall on a poorly defined great circle, or are too scattered to define a great circle. No consistent pattern of overprinting of folds was observed.

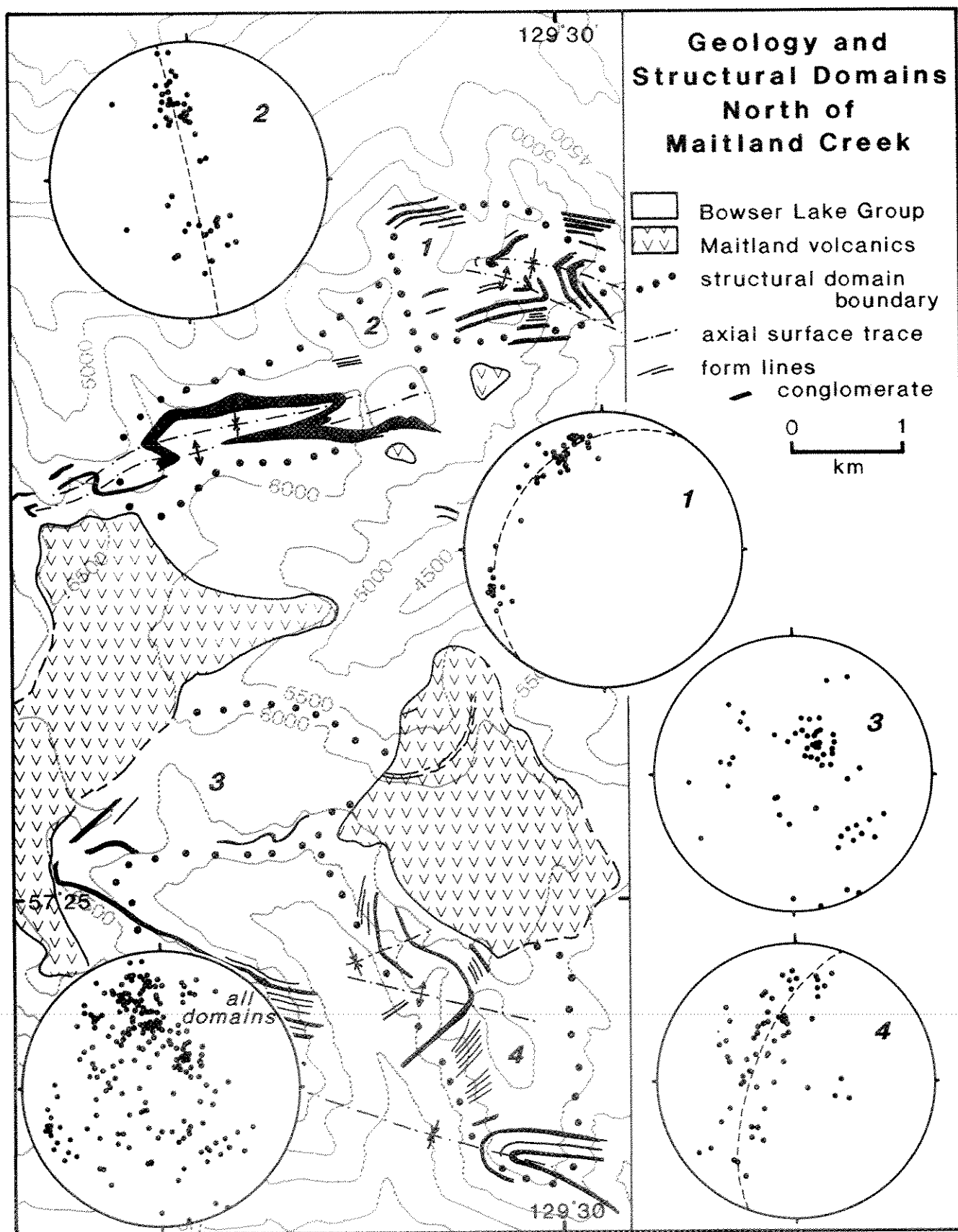


Figure 8. Map of Maitland volcanics and structural domains in the Bowser Lake Group north of Maitland Creek. In this region the lower contact of the Maitland volcanics follows irregular pre-Pliocene topography through more than 300 m of relief, in contrast to areas to the west where it follows a peneplain. The stereonets of poles to bedding in the Bowser Lake Group illustrate how a region of apparently complicated folding, shown by the stereonet of all domains, can be divided into domains of roughly cylindrical folding.

The shape and tightness of folds vary across the area. Gentle large scale folds in the northwest, near the contact with the Hazelton Group, contrast with most of the rest of the study area where folds are generally smaller scale, close or tight (compare sections in Fig. 6). Thrust faults are present, but the lack of markers prohibits estimates of stratigraphic throw.

Summary of structural style

Axial surfaces of folds in west Spatsizi map area range in trend from northeast, north-northeast, northwest, west-northwest, and west. The variety in trends contrasts with the consistent northwest trends of folds in central and east Spatsizi map area (Evenchick, 1988, 1989). In some areas the different trends interfere or are noncylindrical, producing complicated fold patterns, but other areas are dominated by only one trend of folds.

Stratigraphic relationships in west Spatsizi map area provide few constraints on the timing of deformation. Folds must be younger than the youngest Bowser Lake Group, which is Late Jurassic in this region, and older than the Maitland volcanics, which are Early Pliocene.

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