STRATIGRAPHIC DATING OF FAULT SYSTEMS OF THE CENTRAL HUGHES RANGE, SOUTHEAST BRITISH COLUMBIA (82G/12)

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INTRODUCTION

In southeastern British Columbia the northward-plunging Purcell anticlinorium is segmented by several major northeast-trending transverse faults (Rice, 1937; Leech, 1962; Höy, 1982). These faults have various senses of offset and show evidence of reactivation. They have been active at various times including the Middle Proterozoic (Höy, 1982; McMechan and Price, 1982), Late Proterozoic (Lis and Price, 1976), Early Paleozoic and Early Cretaceous (Leech, 1958, 1962; Benvenuto and Price, 1979). Within the Purcell anticlinorium there are several significant mineral deposits, some of which are cut by these transverse structures. The largest of these, the Sullivan lead-zinc "sedex" deposit, is cut by an extensional structure, the Kimberley fault, which has been linked to the Lewis Creek fault across the Rocky Mountain Trench and into the Hughes Range.

The Hughes Range between Skookumchuck (49°55′) and Bull River (49°30′) (Figures 1-2-1 and 2) forms the east wall of the Rocky Mountain Trench. It is the uplifted footwall block of the Rocky Mountain Trench normal fault, and is the offset counterpart of the east flank of the Purcell anticlinorium, the main part of which lies west of the trench in the hangingwall of the normal fault. In the Hughes Range, the Middle Proterozoic Purcell Supergroup rocks, which host the Sullivan deposit on the west side of the trench, are overlain unconformably by a Lower Paleozoic carbonate platform succession. The stratigraphic sequence comprising the Hughes Range has been overthrust, along the Lussier Creek fault, onto the thick Lower Paleozoic shale-carbonate facies that is characteristic of the western Main Ranges and Western Ranges of the southern Canadian Rockies (Leech, 1958).

Several northeast-trending transverse faults cut the Purcell succession and parts of the Lower Paleozoic succession in the Hughes Range. Relationships along unconformities within and at the base of the Lower Paleozoic strata provide evidence of the nature and timing of displacement on these faults. Field mapping of the faults and unconformities bounding three Lower Paleozoic formations have been the main focus of this study.

The Lussier Creek fault trends north for most of its length, but at the south end of the Hughes Range swings northeast, parallel to the transverse faults in the Purcell anticlinorium. Towards the Rocky Mountain Trench, the fault merges with an old transverse fault, the Boulder Creek fault (Figure 1-2-1).

The preliminary results presented here are the product of fieldwork on this project which was carried out in June, July and August, 1991. In addition to field mapping and data collection, samples have been collected for geochronologic (K-Ar) studies to constrain ages of volcanic sequences and postorogenic granites. A new facility at Queen's University is being used to produce computer-generated geological maps of the area. Geographic information systems (GIS) technology is being used to store multiple data sets and analyse fault configurations and paleogeography in the region.

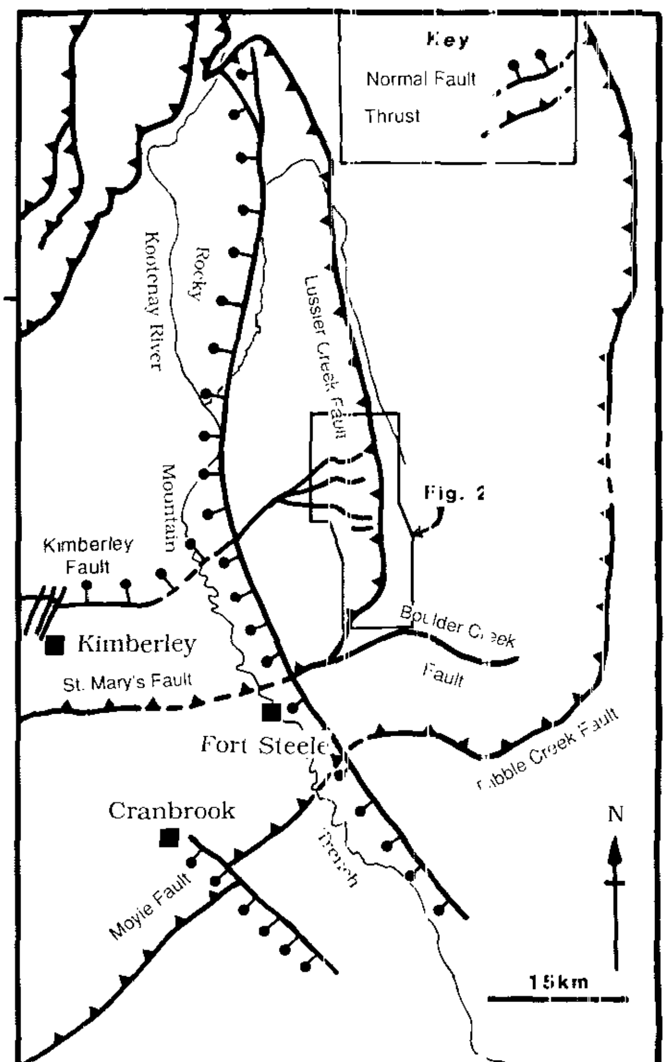

Figure 1-2-1. Location map of the study area. The figure also shows major faults in the region.

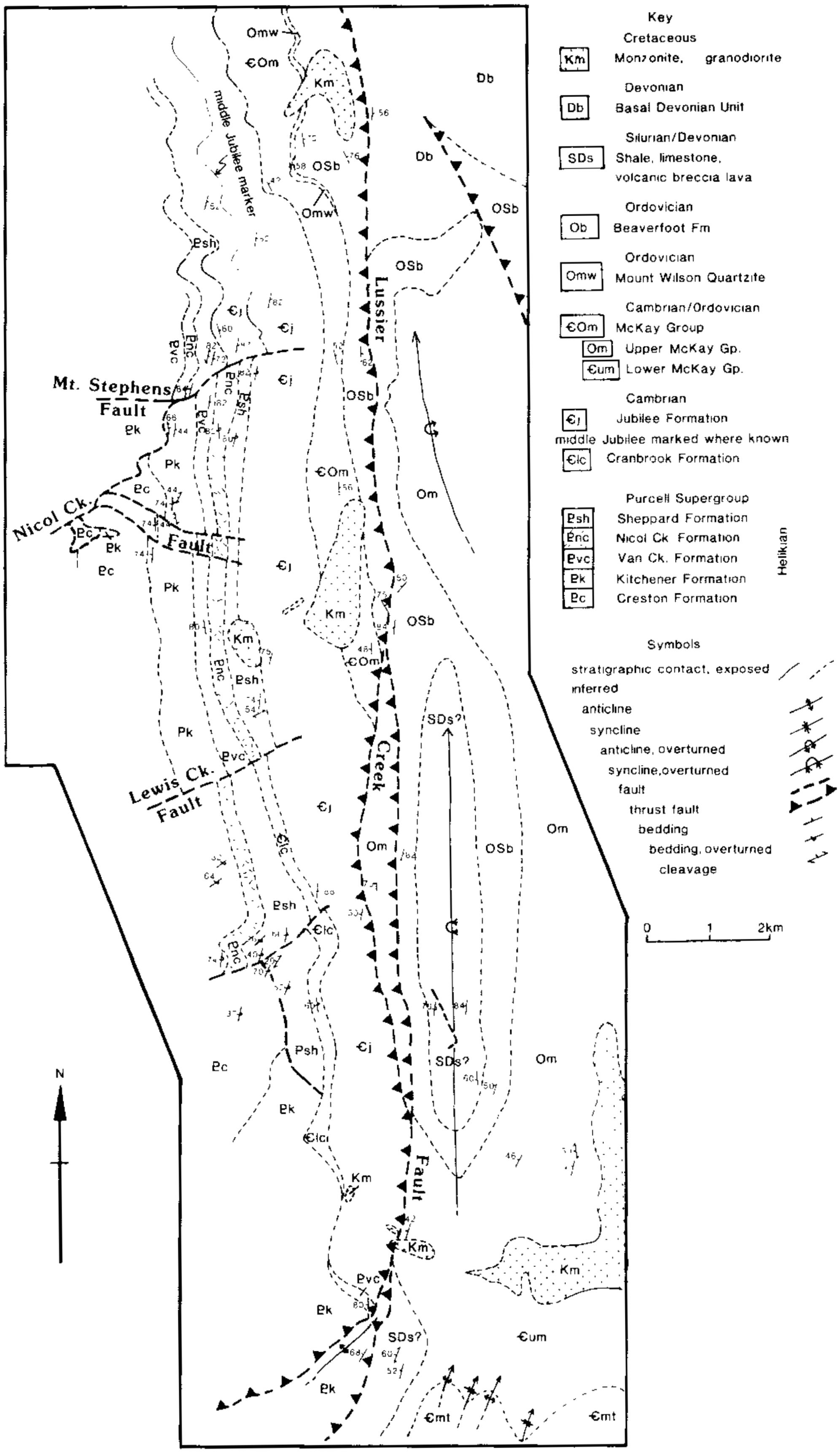

Figure 1-2-2. Geological map of the study area. The data are from 1991 field work, plus Höy (1979, 1988, and personal communication) and Leech (1958, 1960).

REGIONAL GEOLOGY

The Hughes Range lies in the western part of the Cordilleran fold and thrust belt (Figure 1-2-1). It is underlain by the Lussier Creek fault, a major eastward-verging thrust. The fault is part of the regional thrust-fault system that separates east-verging structures of the Purcell anticlinorium to the west, from the west-verging structures of the Porcupine Creek fan structure to the east (Price, 1981, 1986).

Transverse, northeast-trending fault structures are characteristic of this part of the Cordillera (Höy, 1982). They segment the Purcell anticlinorium and extend across the Rocky Mountain Trench into the western Rockies. The two main transverse structures, the St. Mary - Boulder Creek fault to the north, and the Moyie - Dibble Creek fault to the south, are both northwest-dipping, right-hand reverse faults. Profound variations in stratigraphic relationships beneath the sub-Cambrian unconformity indicate that the St. Mary fault follows the locus of a Late Proterozoic structure along which the northwest side was downdropped (Lis and Price, 1976). Similar variations in stratigraphic relationships beneath the Upper Devonian Fairholme Group indicate that the Moyie and Dibble Creek faults follow the locus of an Early Paleozoic structure that was downdropped to the northwest (Leech, 1958; Benvenuto and Price, 1979; McMechan and Price, 1982).

PREVIOUS WORK

Interest in the geology of the Hughes Range (Figures 1-2-1 and 2) and the surrounding areas was initially driven by the discovery of placer gold deposits of the Wild Horse Creek during the 1800s. Exploration interest has continued ever since.

The first detailed work in the range was in the Wild Horse River region (Rice, 1937). The whole of the Hughes Range was mapped at a scale of 1 inch to 2 miles and was published by the Geological Survey of Canada in 1958 (Leech, 1958). The first detailed mapping was by Höy, who demonstrated the influence of faulting on the deposition of the Purcell Supergroup (Höy, 1982, 1985; Carter and Höy, 1987).

STRATIGRAPHY OF THE HUGHES RANGE

THE PURCELL SUPERGROUP

The Purcell sequence in the Hughes Range, where complete, consists of ten formations and reaches a thickness of approximately 7 kilometres (Höy, 1985, in preparation). The lowermost seven formations are exposed in the central Hughes Range, northeast of Fort Steele. Only the upper part of this succession was studied during this project.

The lowest part of the succession comprises the Fort Steele Formation, a sequence of quartzites, argillites and conglomerates which are only found east of the Rocky Mountain Trench. It is overlain by the Aldridge Formation which is a thick (up to 6 km) sequence of fine-grained turbidites that consist of quartzite, quartz wacke and argillite.

The Creston Formation, which overlies the Aldridge Formation, is the stratigraphically lowest formation exposed in the study area. It consists of green, thickly bedded quartzites and argillites and is approximately 2 kilometres thick. A thick carbonate sequence, the mainly buff-weathering, thickly bedded Kitchener Formation, overlies the Creston Formation and is a distinctive marker unit.

The upper part of the Purcell Supergroup consists of dominantly shallow-water argillaceous clastic and carbonate rocks, with a distinctive volcanic sequence in the middle. The Van Creek Formation (McMechan *et al.*, 1980) which is up to 850 metres thick, consists of green and purple siltites and argillites which become tuffaceous at the top. It is overlain by the Nicol Creek Formation (McMechan *et al.*, 1980) which contains dark green, basaltic and andesitic lavas and tuffs, commonly in association with argillites, siltites and sandstones. The lavas are generally amygdaloidal, which helps to distinguish them from thick sills that cut the Creston and Kitchener formations.

The Sheppard Formation lies with sharp contact on the Nicol Creek Formation, and is the uppermost part of the Purcell Supergroup exposed in the study area (Figure 1-2-2). It is a series of red and green dolomitic siltstones and dolomitic sandstones, with a distinctive stromatolitic dolomite near the top. Clast-supported breccias occur within the formation near faults, and may indicate Sheppard-age syntectonic sedimentation.

At the northern end of the Hughes Range, north of the study area, younger parts of the Purcell Supergroup (Gateway, Phillips and Roosville formations) and part of the Windermere Supergroup are preserved under the sub-Cambrian unconformity.

LOWER PALEOZOIC ROCKS

Contrasting Lower Paleozoic sequences occur in the hangingwall and footwall of the Lussier Creek fault. The hangingwall sequence is a relatively thin (*ca.* 2.5 km) carbonate platform sequence; whereas the footwall sequence is a thick (*ca.* 6 km) shale-carbonate sequence. Both the hangingwall and footwall successions begin with Lower Cambrian siliciclastic formations, but these are laterally variable.

Four unconformity-bounded formations are found in the hangingwall of the Lussier Creek fault. They range in age from Cambrian to Ordovician and they vary in thickness along strike. The two oldest, the Cranbrook and Jubilee formations, are offset by transverse northeast striking synsedimentary faults, which do not offset the younger formations. The distribution of the Cranbrook Formation is controlled by the sense of displacement on these faults, and by erosion prior to deposition of the Jubilee Formation.

The Lower Cambrian Cranbrook Formation which forms the base of the Lower Paleozoic sequence, is dominated by white quartzite and includes major components of quartz wacke and conglomeratic sandstone (as much as 60% locally). The Cranbrook Formation, although widespread elsewhere north of the Moyie - Dibble Creek fault, is absent beneath the Jubilee Formation throughout most of the map area. It is preserved locally beneath the sub-Jubilee unconformity adjacent to the transverse faults in the central Hughes Range. The shale-dominated Eager Formation, which is also widespread regionally in the hangingwall of the Moyie - Dibble Creek Fault, is absent from the study area.

The base of the carbonate sequence is marked by the Middle to Upper Cambrian Jubilee Formation (Leech, 1958), which is characteristically a well-bedded limestone/dolomite in its lower part, but more massive in its upper part. In the northern part of the study area, there is a rusty weathering dolomitic unit in the middle part of the Jubilee Formation that is a good marker horizon. Evidence of synsedimentary tectonism was found towards the base of the formation in the form of extensional structures within layers of sediment, and sediment dikes along fault traces.

The McKay Group (Leech, 1958) is a shaley limestone at its base, but becomes progressively more characteristic of carbonate platform facies toward the top, with intraformational conglomerates, peloidal wackestones, nodular limestones and bioclastic grainstones. To the north of the field area, the Middle Ordovician Mount Wilson quartzite unconformably overlies the McKay Group (Leech, 1954; Norford, 1969). Elsewhere this quartzite is absent and carbonates make up the top of the group.

The Beaverfoot Formation, an Upper Ordovician and Lower Silurian carbonate platform deposit (Norford, 1969), rests unconformably on the McKay Group except where the Mount Wilson quartzite is present. It consists of thick-bedded dolomitic limestones and dolomite and is characterized by chert nodules and a mottled texture. The top of the formation is truncated by the Lussier Creek fault; but north of the study area it is overlain by Middle Devonian gypsum, shale and carbonate rocks (Leech, 1958).

The Paleozoic rocks in the footwall to the Lussier Creek fault differ significantly from those in the hangingwall. The Purcell sequence is overlain by the quartzites of the Cranbrook Formation which grade upwards into the shale of the Eager Formation (Leech, 1958). The overlying succession comprises the shales of the Tanglefoot unit (Thompson, 1962), the McKay Group, Beaverfoot Formation and a "Silurian-Devonian unit" (Leech, 1960).

The Tanglefoot unit has a thick, laminated, basinal carbonate-rich shale at its base and consists of sandstones and possible storm-influenced limestones at the top. It appears to be a deep-water equivalent of the Jubilee limestones and dolomites. The top of the McKay Group is similar to that in the hangingwall of the Lussier Creek fault and contains nodular limestones. The lower part is a shaley limestone and is very thick (greater than 1 km). The Beaverfoot Formation is of similar thickness and appearance to the hangingwall Beaverfoot.

The Silurian-Devonian unit has been described in detail by Leech, (1958). Examination in the field shows it to be series of shaley limestones overlain by laterally discontinuous volcaniclastic rocks, basaltic lavas and tuffs, above which are more shaley limestones and to the south, bioclastic limestones. The sedimentary sequence is characterized by slump structures (up to 1 m), breccias containing many dolomitic and volcanic clasts and small-scale synsedimentary faults. In addition to a major north-trending syncline containing this unit (Leech, 1958), this unit has been found in the immediate footwall of the Lussier Creek fault in the extreme south of the map area. In the north of the study area it overlies the Beaverfoot Formation, while in the south it overlies the McKay Group.

STRUCTURE

Three main sets of faults occur in the study area; older northeast-trending transverse faults which generally only cut the Purcell and lower part of the Lower Paleozoic sequences; north-trending thrust faults; and north-trending normal faults that are associated with the Rocky Mountain Trench normal fault.

TRANSVERSE STRUCTURES

Five transverse faults cross the central Hughes Range. These are from north to south; the Mount Stephens, Nicol Creek, Lewis Creek, and two unnamed faults. The three named faults merge southwestward towards the Rocky Mountain Trench, and can be correlated across the trench with the Kimberley fault, which cuts the Sullivan ore deposit. Stratigraphic relationships at the sub-Jubilee unconformity show that these faults were active prior to deposition of the Jubilee Formation. They were tilted or overturned during the development of the Purcell anticlinorium, the east flank of which is the hangingwall of the Lussier Creek fault. They cut bedding at high angles, and therefore must have been steeply dipping when they formed.

The sense of stratigraphic separation changes from one fault to another and in the case of some faults, along their length. The Mount Stephens and Nicol Creek faults have reverse separations; separation on the Lewis Creek fault is normal. The two unnamed faults have complex relationships. The northernmost has a reverse-sense offset at its tip, but has a normal offset farther down its length. The other abuts the first and appears to be overlapped by the sub-Cambrian unconformity. The sense of displacement is uncertain.

A late, low-angle, west-side-down normal fault connects the Nicol Creek and Mount Stephens faults (Höy, 1979). As these faults are lateral structures bounding the hangingwall block to this normal fault, they must incorporate a component of offset related to displacement on the normal fault. Thus some of the apparent offsets observed along faults are the result of only partial reactivation of old faults by new structures.

AGE OF FAULTING

By comparing fault offsets of bedding above and below various regional unconformities, the relative timing of some of the offset history can be established. At the east end of the Mount Stephens fault, near where it dies out in the Jubilee Formation, both upper Purcell rocks and the Jubilee Formation show a reverse sense of offset relative to the horizontal datum provided by the bedding. The fault does not offset the upper part of the Jubilee Formation, but local thinning of the overlying McKay Formation above the fault

(Figure 1-2-2) may be either a compaction effect, or the result of continued displacement. This constrains the last age of offset on this fault to the Cambrian. A greater offset at the level of the Purcell Supergroup compared to the offset of the Jubilee Formation indicates that there was additional reverse offset prior to deposition of the Jubilee. This may be related to tectonic activity during deposition of the Sheppard Formation, as evidenced by changes of thickness and facies (*see* Stratigraphy section).

The Nicol Creek fault also has a reverse offset, and relative to the horizontal datum provided by the bedding, it appears to die out upward into the Jubilee Formation. The Lewis Creek fault is marked by normal offset of the upper part of the Purcell Supergroup and the base of the Jubilee Formation, and also dies out within the Jubilee Formation. Cranbrook strata are preserved beneath the Jubilee Formation in the hangingwall; but the Jubilee Formation is unconformable on the Sheppard in the footwall (Figure 1-2-2). This shows that the fault was active during the interval between the deposition of the Cranbrook and Jubilee Formations.

The northern unnamed transverse fault has a thick Cranbrook succession in the hangingwall, including a facies containing a conglomeratic wacke, suggesting Early Cambrian extension. The southern fault is truncated by the sub-Cambrian unconformity and overlain by the Cranbrook Formation, indicating faulting took place prior to Cambrian sedimentation.

Synsedimentary faulting is recorded at several stratigraphic levels in the Hughes Range. Höy (1982, in preparation) reported block faulting during deposition of the Aldridge Formation. Thickness and facies-change patterns are indicative of faulting during deposition of the Sheppard Formation. Both reverse and normal offset occurred during the Cambrian. In the footwall of the Lussier Creek fault, there is evidence of extensional faulting during the deposition of the Silurian-Devonian unit. Regionally, the overlap at the base of the Upper Devonian Group onto different stratigraphic sequences indicates significant Middle to Late Devonian tectonic activity (Benvenuto and Price, 1979).

North-Striking Major Thrusts

The second important set of faults in the region are north-trending thrusts in both the hangingwall and footwall of the Lussier Creek fault. Those in the hangingwall are east verging, but those in the footwall are part of the west flank of the structural fan of the Porcupine Creek anticlinorium and verge to the west (Price, 1986). The Lussier Creek fault itself has a northerly trend along most of its length, but swings into a northeast orientation at the south of the map area where it converges with the Boulder Creek fault (Leech, 1958), a reactivated older transverse structure.

The timing of displacement of the north-trending faults is constrained by the fact that they cut rocks as young as Devonian (Leech, 1958), but are pinned by monzonitic to granodioritic intrusions of mid-Cretaceous age (Höy and van der Hayden, 1988). A few additional small intrusive bodies were discovered in the study area during 1991 (Figure 1-2-2).

CONCLUSIONS

Northeast-trending transverse structures in the hangingwall of the Lussier Creek fault were active during Aldridge time and subsequently during deposition of the Nicol Creek (Höy, 1982) and Sheppard formations. Reactivation of these structures took place during the Cambrian, prior to deposition of the Jubilee Formation and, at least locally, during deposition of the lower part of the Jubilee Formation. The tectonic setting during late Purcell and Cambrian time is not clear. Both reverse and normal offsets along steep faults during the Cambrian point to strike-slip motion, with localized transpression and transtension. A similar tectonic regime may have operated during late Purcell time, but because of the large time interval between the Middle Proterozoic and the Cambrian it must have been a separate tectonic event.

Similar pre-Devonian structures with a northeast orientation, which occur in the Bull River area, define a step on the northwest flank of "Montania", which was a continental platform during Early Paleozoic time (Benvenuto and Price, 1979). The Moyie - Dibble Creek fault system followed this older structure. The positioning of the Lussier Creek fault and its deflection to a northeast trend may be indicative of a similar structural inheritance.

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