The Siberian Connection: A case for Precambrian separation of the North American and Siberian cratons

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ABSTRACT

The hypothesis that the Cordilleran geosyncline originated as an Atlantic-type continental margin by the rifting of an older Precambrian continental mass and the opening of a new ocean basin leads to the question of where the counterpart of the North American Precambrian craton may be. The Siberian platform—a large, discrete, older Precambrian craton, lodged in northeast Asia and surrounded by younger fold belts—is a likely candidate for the missing Precambrian continental fragment. The outline of its northeast margin fits the southwest margin of the North American Precambrian craton to produce a congruence of tectonic grain and age provinces. Both margins are overlapped by sediments of the same general type that began to accumulate about 1,500 m.y. ago, after the initiation of the separation.

THE PREMISE

The earliest part of the record of evolution of the North American Cordilleran geosyncline is fragmentary at best, because the base of the geosynclinal succession is only rarely exposed and its relationships with underlying basement rocks are very poorly known. Nevertheless, middle and late Proterozoic* rocks that emerge locally from beneath the much more widespread Paleozoic deposits show, by their thickness and facies variations, that they are an integral part of the Cordilleran miogeocline—an eastward-tapering wedge of structurally concordant supracrustal rocks that onlaps, with profound angular discordance, the western margin of the early Proterozoic and Archean crystalline basement complex of the North American craton. The fact that the structures in the early Proterozoic and Archean basement complex are truncated sharply against this thick wedge of overlapping supracrustal rocks has led to the hypothesis that the Cordilleran geosyncline originated when rifting of the older Precambrian continental crust and the opening of a new ocean basin produced a new continental margin of the Atlantic type (Stewart, 1971, 1972, 1976; Burchfiel and Davis, 1972, 1975; Gabrielse, 1972; Monger and others, 1972; Harrison and others, 1974). This very attractive hypothesis immediately leads to the question of where may be the counterpart crustal mass that was separated from the North American craton.

The Siberian platform—a large, discrete, older Precambrian craton, lodged in northeast Asia and surrounded by younger geosynclinal fold belts—is a likely candidate for this missing fragment for three reasons: (1) Paleomagnetic and regional tectonic data suggest that the Siberian platform is allochthonous relative to pre-Mesozoic Russia, and that it is one of many distinct subcontinents that have been welded together by plate-tectonic processes to form the present-day mosaic of Asia (Hamilton, 1970; Burrett, 1974). (2) The tectonic grain defined by older Precambrian crustal structures and the boundaries between tectonic provinces of different ages appear to be truncated along the northeastern margin of the Siberian platform, which fits hand-in-glove with the western margin of the North American Precambrian craton to produce a congruence in tectonic grain between the two plates of Precambrian continental crust. (3) The oldest supracrustal rocks that overlap the truncated northern margin of the Siberian platform are broadly coeval with those that overlap the truncated western margin of the North American craton.

THE MATCH

A reconstruction of the Siberian-American craton (Fig. 1) involves fitting a prominent salient and re-entrant on the north side of the Siberian platform to a matching re-entrant and salient on the southwest side of the North American craton. Although the precise location of the southwestern margin of the North American Precambrian crystalline basement has not been established, the approximate edge of the Precambrian continental crust beneath the Cordillera can be taken as the western edge of the Cordilleran miogeocline, west of the last-known exposures of Precambrian crystalline basement rocks that are more than 1,500 m.y. old. The western limit of older Precambrian continental basement inferred from initial ratios of Sr isotopes in plutonic rocks of the United States Pacific Northwest (Armstrong and others, 1977) locally lies slightly west of this. The boundaries of the fragment of older Precambrian continental crust in Siberia (Fig. 1), outlined from the analysis of geophysical and regional tectonic data, are inferred to generally follow zones of "geosutures" and "deep faults," along which the magnetic signature of the crystalline basement is truncated (Savinskiy and others, 1973; Rezanov and Zarudnyy, 1966).

Our reconstruction is based on the assumption that the shapes of the Siberian and North American cratons, along the edges that we have matched, have not changed significantly since the separation began. We recognize that there have been changes in the shapes of these two margins since the separation began; but changes

*We use the terms early, middle, and late Proterozoic to denote the approximate time intervals, 2,500 to 1,700 m.y., 1,700 to 900 m.y., and 900 to 600 m.y., respectively.

such as the compression across the North American margin in Mesozoic and early Cenozoic time and the extension associated with the development of the Basin and Range province of the United States in late Cenozoic time, although not established with much precision, do appear to be relatively insignificant at the scale of the reconstruction portrayed in Figure 1.

To establish the most likely relative locations of the two fragments in the reconstruction requires some compromise between the best match of the shape of the approximate boundaries and the best alignment of structural grain in the older Precambrian crystalline basement in both cratons. In the reconstruction produced in this way (Fig. 1), the pronounced northeastward-trending structures of the Churchill province of the Canadian Shield are brought into alignment with the similar structures in the adjacent and coeval Anabar-Aldan province of the Siberian platform; the Archean cratonic remnants that comprise the Superior and Wyoming provinces are brought into alignment with the Tyunga and Aldan Archean cratonic remnants in Siberia; and the irregular margins of the two older Precambrian basement fragments are fitted together. The resulting relatively insignificant gaps (or overlaps) in the fit along the margins of the two crustal plates may be ascribed to crustal attenuation or other tectonic modifications that occurred subsequent to the beginning of the separation.

Detailed correlation of crystalline basement rocks between the two cratons is hindered by deep burial and very limited exposures in the zone close to their common margin. On the Siberian platform the total area of exposure of crystalline basement rocks is particularly small; however, data from deep wells, aeromagnetic and gravity surveys, and basement-rock xenoliths have been used to outline the general patterns beneath the sedimentary cover there, in much the same way as in North America.

Gafarov (1970) distinguished two types of provinces in the basement of the Siberian platform on the basis of aeromagnetic anomaly patterns: (1) Ovoid areas characterized by irregular, curvilinear anomalies were assumed to mark Archean gneissose massifs. They are separated by (2) wide zones of regular, northeastward-trending linear anomalies. The northeastward-trending anomalies can be shown to parallel the structural grain of Archean (~2.7 b.y. old) granulite facies rocks and anorthosite massifs that were deformed

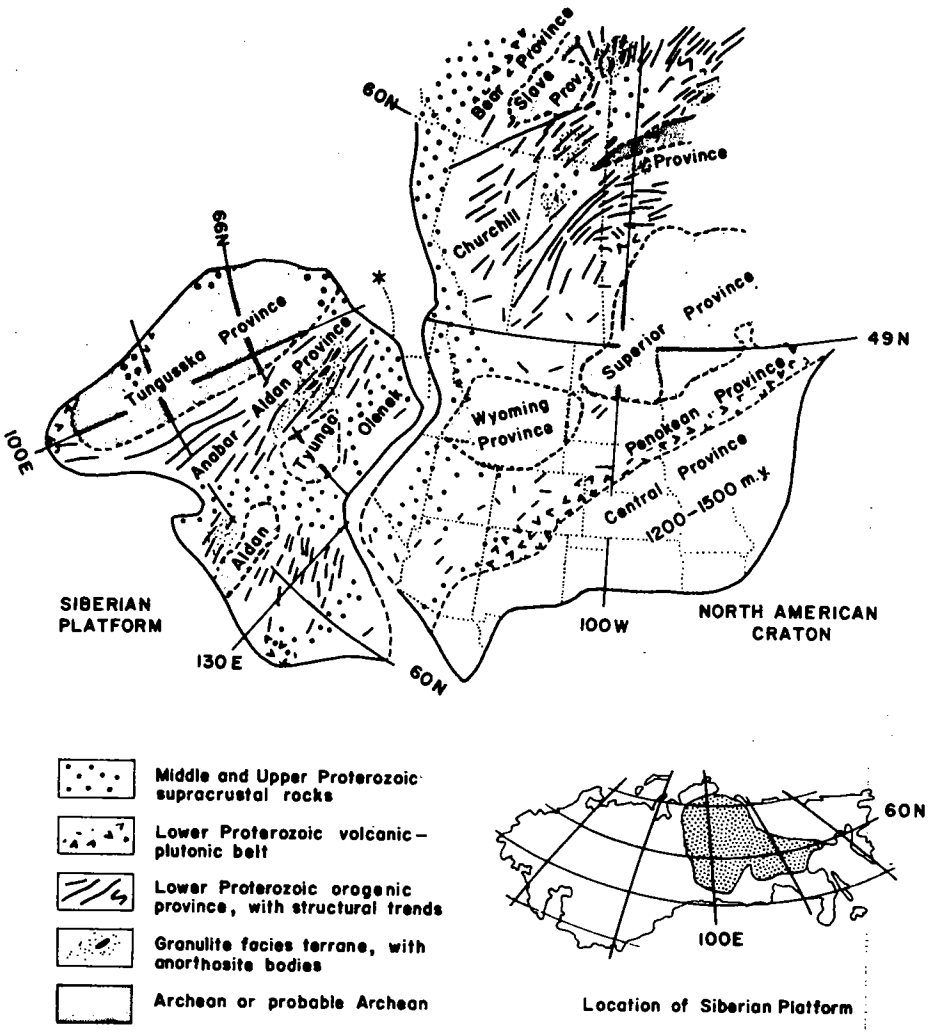

Figure 1. Reconstruction of the Siberian-American Precambrian craton. Based on data for the Siberian platform from Gafarov (1970), Khrenov and Bukharov (1973), Klitin (1976), Kosygin and Parfenov, (1975), Savinskiy and others (1973), and Tectonic Map of the USSR, 1964; and on data for North America from Armstrong and others (1977), Bayley and Muehlberger (1968), Coles and others (1976), Condie (1976a, 1976b), Davidson (1972), Gabrielse (1972), Stewart (1972), Stockwell and others (1970). Asterisk indicates western limit of Precambrian continental crust based on Sr-isotope initial ratios (after Armstrong and others, 1977).

and retrograded to amphibolite facies during early Proterozoic time, 1,700 to 2,100 m.y. ago (Akimov and Genshaft, 1973; Mikhaylov, 1973; Kosygin and Parfenov, 1975). The average K-Ar age of micas from the platform basement is 1,800 to 2,100 m.y., with U-Th-Pb ages greater than 3 b.y. (Kosygin and Parfenov, 1975), and the craton appears to have been stabilized about 1,700 to 1,750 m.y. ago (Til'man and others, 1975).

The crystalline basement provinces of the Siberian platform conform closely with those of the North American craton. The Siberian Tungusska, Aldan, and Tyunga massifs of probable Archean age are coeval with the Slave, Superior, and Wyoming Archean provinces of North America. The Anabar-Aldan province of Siberia fits against the Churchill province of North America, which also is made up largely of Archean rocks, including granulite terranes with anorthosite massifs that were deformed and retrograded to amphibolite facies, and also was stabilized about 1,750 m.y. ago during the Hudsonian orogeny (Stockwell and others, 1970, p. 49). Early Proterozoic metasedimentary rocks in the Olenek area of Siberia (Kosygin and Parfenov, 1975) may be correlative with early Proterozoic geosynclinal belts within the Churchill and Penokean provinces of North America. The eastern and southwestern margins of the Siberian platform are rimmed by volcanic-plutonic belts that range in age from 1,600 m.y. to 2,080 m.y. (Khrenov and Bukharov, 1973). These igneous belts

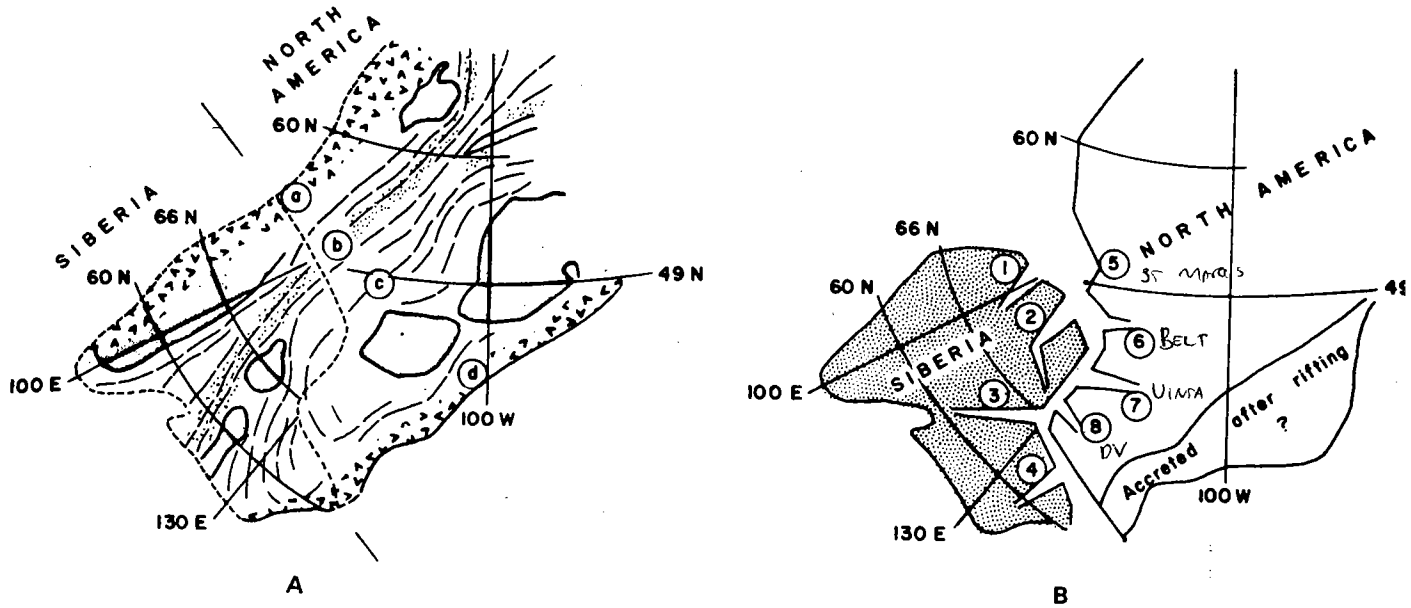

Figure 2. (A) Prerifting correlations between tectonic subdivisions of the Siberian and North American Precambrian cratons. a, Angara-Yniseygraded; c, Wollaston Lake–Olenek orogenic belt; d, Penokean orogenic belt. Dashed line marks locus of separation after rifting. Data generalized from Figure 1. (B) Siberian–North American Precambrian rift system and related fault-bounded basins and aulacogens. 1, west Anabar; 2, Vdzha; 3, Vilyu 4, Sette-Daban; 5, St. Marys; 6, Belt; 7, Uinta; 8, Death Valley; same area and scale as (A).

may be likened to the 1,700- to 1,920-m.y.-old continental margin volcanic-plutonic belt of the Bear province in the Canadian Shield (Fraser and others, 1972) and to the northeast-trending igneous belt that extends from northwestern Mexico to Wisconsin and developed 1,650 to 1,850 m.y. ago (Condie, 1976b). Generalized correlations of basement provinces between the cratons are shown in Figure 2A.

THE SUPRACRUSTAL ROCKS

Riphean (middle and late Proterozoic) sediments cover most of the Siberian platform and pass into thick miogeosynclinal sequences along the southwestern, western, and (presumably) the northern margins of the platform (Keller and others, 1968; Klitin, 1976; Kosygin and Parfenov, 1975). The platform deposits overlie the crystalline basement above a regolith that is in part lateritic (Sklyarov and Khromtsov, 1973), and basal conglomeratic sandstones grade upward into stromatolitic carbonates. The miogeosynclinal deposits are typified by basal arkosic sandstones with till-like conglomerate grading up to terrigenous-carbonate sequences and thick stromatolitic limestones and dolomites (Klitin and Pavlova, 1970; Keller, 1974). The platform is segmented by aulacogens, re-entrants from the miogeosynclines that are filled with Proterozoic and younger sediments, and in some cases with volcanic rocks and alkalic ultrabasic intrusions (Kosygin and Parfenov, 1975). Potassium-argon dates from glauconite indicate sedimentation began along the northern and eastern margins of the platform 1,450 to 1,570 m.y. ago (Semikhatov and others, 1966; Kosygin and Parfenov, 1975).

A similar pattern of Proterozoic sedimentation is recorded in western North America. Middle Proterozoic platformal sediments with basal arkosic and quartzose sandstone and conglomerate and upper stromatolitic dolomite overlie deeply weathered basement rocks in the Canadian Shield and thicken toward the cratonic margin (Fraser and others, 1970). In northwestern Canada thick middle Proterozoic fluvial and shallow-water clastic deposits and stromatolitic dolomites overlap a deformed early Proterozoic continental margin orogenic belt and are believed to pass westward into deeper water equivalents (Fraser and others, 1972). In the southwestern United States and northern Mexico, middle Proterozoic platformal sediments overlie the crystalline basement with profound unconformity and are typified by basal arkosic and conglomeratic sandstones overlain by stromatolitic dolomites, shales, and quartzose sandstones (Shride, 1967; Wright and others, 1976; Noble, 1914; Livingston and Damon, 1968). Miogeoclinal rocks of middle and late Proterozoic age are recognized from British Columbia to California and define the basal units of the Cordilleran geosyncline (Gabrielse, 1972; Crittenden and others, 1972; Harrison and others, 1974). Aulacogen basins extending in from the geosyncline and filled with middle Proterozoic sediments are reported in Arizona, California, Utah, and Montana (Burke and Dewey, 1973; Wright and others, 1976). Sedimentation began about 1,500 m.y. ago in the Belt Basin of northwestern Montana and southern British Columbia (Harrison and others, 1974), and, although not closely bracketed, was well underway 950 to 1,300 m.y. ago elsewhere in the Cordillera (King, 1976; Damon and Giletti, 1961; Livingston and Damon, 1968; McKee and Noble, 1974; Donaldson, 1973).

THE MODEL

The Siberian-American craton was largely stabilized by 1,700 m.y. ago, with intermittent volcanism occurring along the western and southern (relative to North America) margins. Lower Proterozoic continental-margin volcanic-plutonic orogenic belts along the northern border were worn down to become sites for stable continental margin sedimentation during middle Proterozoic time. Around 1,500 m.y. ago a large branching rift system was initiated (Fig. 2B), and as it evolved, perhaps over hundreds of millions of years, the Siberian fragment was rafted away to eventually coalesce with other subcontinents as part of the Asian continent.

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