Zeitschrift: Eclogae Geologicae Helvetiae

Herausgeber: Schweizerische Geologische Gesellschaft

Band: 84 (1991)

Heft: 3: [Emile Argand 1879-1940]

Artikel: The rôle of accretionary wedges in the growth of continents : asiatic examples from Argand to plate tectonics

Autor: engör, A.M. Celâl / Okuroullari, A. Haldun

Kapitel: 6: The palaeotectonics of the Altaids

DOI: https://doi.org/10.5169/seals-166788

The first major collision along the Kuen-Lun/Songpan-Ganzi accretionary complex system occurred when the west and east Qangtang blocks and the Yangtze block collided with it in the latest Triassic to early Jurassic interval along the Ak Tagh ("white mountain")/Lake Lighten/Hoh Xil Shan/Litang/Longmen Shan suture belt (ŞENGÖR et al. 1988; BAUD 1989). This line represents a fundamental boundary in the architecture of the Asiatic Tethysides separating areas of profoundly different structural styles (Fig. 10). To the north, prolonged subduction-accretion through the entire Palaeozoic and early Mesozoic created immense, south-facing Turkic-type orogenic belts dominated by subduction-accretion complexes with no major continental collisions. If there are *any* pre-Palaeozoic continental fragments within the Kuen-Lun/Songpan-Ganzi accretionary complex (e.g. the Songpan Massif?: ŞENGÖR et al. 1988), they most likely represent small Seychelles-type intra-oceanic continental fragments or Baja-California-Type strike-slip generated marginal slivers, with a minimum effect on the orogenic architecture.

By sharp contrast, to the south of the Ak Tagh/Lake Lighten/Hoh Xil Shan/Litang/Longmen Shan suture belt, the orogenic style is dominated by ordinary Himalayan-type mountain belts formed from the collision of major pieces of Gondwana-Land calved off its northern margin since the middle Palaeozoic (ŞENGÖR et al. 1988). Here, subduction-accretion complexes are much smaller and are found either squeezed into narrow linear suture zones or expelled in thin, long-travelled overthrust sheets (cf. GANSSER 1974). In contrast to the northern Turkic-type orogens, most arcs in the Himalayan-type orogens are constructed through old continental crust (GARIÉPY et al. 1985) with few exceptions formed directly on ocean floor (TROMMSDORFF et al. 1982).

6. The Palaeotectonics of the Altaids

When we take a close look at the palaeotectonics of Central Asia north of the Tethysides, we notice that the Turkic-type orogenic architecture dominates the structure of an immense tectonic collage that surrounds the Angara craton like a richly ornamented necklace in the west, south and southeast, and which was named by Eduard SUESS (1901, p. 250) the *Altaids*[18]). The Altaids consist almost entirely of

[18]) SUESS (1901, p. 250) defined the Altaids as follows: "In order to obtain an approximate idea of the configuration which is thus developed, let us imagine the whole of that part of Asia which lies to the south-west to be covered with water. Let an impulse originate from the Irtish or the Tarbagatai toward the south-west. Numerous long mountain waves arise one behind the other; at first they are more or less convex towards the south-west, as in the branches of the Thian-shan. They broaden out and elongate, or diverge from one another, where they find room enough, as on the Tchu and Ili. They crowd together and rise, towering up, where the space grows narrower, as in the Nan-shan. In places, they sweep past obstacles, stiff and straight, as in the Tsin-ling-shan, continually seeking a lateral prolongation; in other places, on the contrary, they are impeded by these obstacles, bent and turned aside. At first the universally predominant direction is to the north-west or west-north-west. It is these folds or waves that we group together as the *Altaids*".

The Altaids comprise much of what Suess termed the Asiatic structure, but it was mainly the core of Central Asia that he had in mind for the type Altaids. One of us suggested elsewhere (ŞENGÖR 1987) that this is how we should now best use the term Altaids and thus restricted them between the Angara craton and the Tethysides as Fig. 10 shows.

Palaeozoic and subordinate latest Proterozoic and early Mesozoic subduction-accretion complexes with vanishingly small areas of Precambrian continental crust that in places forms cores of Altaid magmatic arcs as largely recognised by Peive et al. already by 1976 (Peive et al., undated). Fig. 10 exhibits an incomplete tectonic map showing the extent of some of the major Altaid accretionary complexes. As in the Kuen-Lun, many of these were later invaded by arc magmas and became arc massifs to younger subduction-accretion prisms. The detailed description of the whole of this vastly complicated tectonic collage cannot be given here owing to space shortage, but will appear elsewhere (Şengör, Okuroğullari & Hsü, in prep.). In the following subsection we outline the tectonics of a small but representative section of the Altaids, namely the Central Kazakhstan ranges.

6.1 Palaeotectonic evolution of Central Kazakhstan

Fig. 16 is a highly simplified and schematized tectonic map of the northern and central parts of the Kazakhstan Continent of Zonenshain (1973) and Zonenshain et al. (1990) or Kazakhstania of Ziegler et al. (1979). Precambrian continental crust exists in the north, in the Kökchetav ("Mountain of Kökche") Massif (Golovanov et al. 1969) and in the west, in the Ulutau ("Great Mountain") Massif. Smaller slivers of Precambrian continental crustal material have been reported also from the highly fragmented Yerementau and the Aktau-Mointy massifs (Karyayev 1984; Mossakovsky & Dergunov 1985). A scatter of isotopic ages, mostly of sixties vintage, and ranging from a Rb-Sr phengite age of 1,300 ± 200 to a Zr age of 1,040 Ma on a granitic gneiss has been reported from the basement of the Kökchetav Massif (Sobolev et al. 1982). The oldest unconformable shallow marine Vendian-Cambrian[19]) quartz-bearing arkoses contain detrital zircons dated at 1,200 ± 100 Ma, providing a lower age limit (Sobolev et al. 1982). The oldest sequences in the Ulutau Massif consisting of a Vendian-Cambrian quartz-arkose provide similarly old detrital zircons (1,220 ± 100 Ma:

In the present usage of the Soviet geologists, what we call the Altaids corresponds largely, but not entirely, with the "Central Asian Folded Region" (Yanshin et al. 1966, pp. 162ff), "Central Asian Foldbelt" (Zonenshain et al. 1990, fig. 1 and pp. 55ff) or "Central Asian Mountain Belt" (Khain 1990). Dr. Lev P. Zonenshain (pers. comm., 1991) suggested that we use the Soviet term rather than Suess' designation. However, not only is "Central Asia" a vague geographical concept, no longer used by geographers (for the vagueness, see the discussion in von Richthofen 1877, pp. 3–8; for the current geographical usage see Domrös et al. 1981, p. 191) but the Soviet term "Central Asian Foldbelt" leaves out both the Urals and the Mongolo-Okhotsk Orogenic Complex (e.g. Yanshin et al. 1966; Zonenshain et al. 1990), which the term Altaid includes. Because in this study we include in our discussion the entire late Proterozoic to middle Mesozoic orogenic collage that accreted around the Angara craton with the exception of its northeastern margin, "Altaid" is preferable to just "Central Asian Foldbelt". That is also why Şengör (in press) has abandoned his earlier suggestion to call the Turkic-type orogenic belts "Central Asian type" (Şengör 1991b).

[19]) Mossakovsky & Dergunov (1985, p. 1207) give the age of the deposit in the Kökchetav as Vendian. However, Jagoutz et al.'s (1990) 533 + 20 Ma metamorphic age of the basement underlying the unconformable deposits would make this age impossible, even within the limits of error of the isotopic dating according to both the DNAG and the Harland et al. (1989) time scales. That is why we gave the age as Vendian-Cambrian. However, a Vendian age becomes possible, if the base of the Cambrian can be pulled up to 550 Ma (on the basis of Dallmeyer & Gibbons' 1987, $^{40}Ar/^{39}Ar$ mineral dates of the Penmynydd schists in Anglesey: W.S. McKerrow, written comm., 1988).

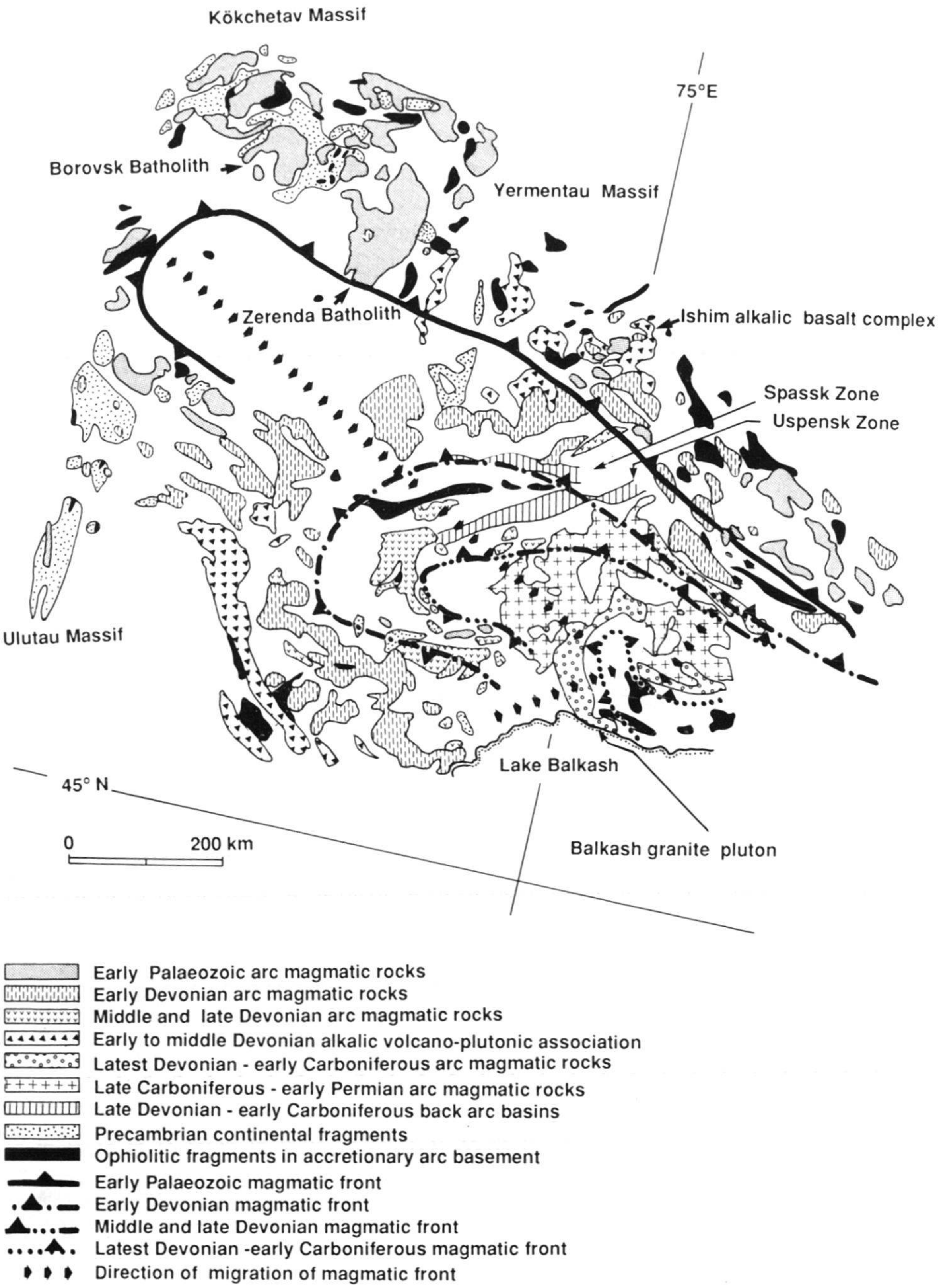


Fig. 16. Schematic tectonic map of Central Kazakhstan showing the positions of successive palaeomagmatic fronts and the associated arc-related plutons. Also shown are the Precambrian continental slivers and the Spassk and Uspensk late Devonian-early Carboniferous marginal (?back-arc) basin remnants. The map was simplified from Karyayev (1984, fig. 1). For location, see Fig. 10.

Sobolev et al. 1982) that led Mossakovsky & Dergunov (1985, p. 1207) to suggest that the Kökchetav and the Ulutau massifs may have had a common cover sequence consisting of shallow water quartzites. More recent studies have shown that in the Kökchetav Massif metamorphic diamonds, indicating pressure values of ≥ 40 kbar and temperatures > 900–1,000 °C, were formed during a subduction episode at 533 ± 20 Ma BP that metamorphosed rocks that had largely formed more than 2 Ga ago (Jagoutz et al. 1989; Sobolev & Shatsky 1990).

As the map shown in Fig. 16 displays, a remarkably concentric arrangement of magmatic arcs of various ages is seen in Central Kazakhstan, whereby the innermost arc is the youngest (see also Karaulov 1981, and Markova 1982, fig. 1). With the exception of a few slivers of continental crust already mentioned, the oldest of these arcs that probably already had begun developing in the latest Proterozoic in the Chinghiz-Tarbagatai range, grew on oceanic crust (Markova 1982, fig. 16, loc. 7; Karyayev 1984; Kheraskova 1986) and in the northwest may have been responsible for generating the diamondiferous ultra-high pressure metamorphic rocks in the Kökchetav Massif. The Cambro-Ordovician rocks of the Central Kazakhstan area consist both of volcanic (e.g. Dzhangabul, Ashchikol, Köksengir, Kendykta, and Sagsk suites: Karyayev 1984) and sedimentary assemblages. Of the sedimentary rocks, the Cambrian deposits consist generally of cherts and oceanic mudstones (e.g. Akdym, Kosgobay, and Tekturmay suites; Karyayev 1984), whereas Ordovician rocks are mainly flyschoid clastics (e.g. Yerkebidaik, Angrensor, Sargaldak, and Lidiyevsk suites: Karyayev 1984). But even what Karyayev (1984) calls "island arc/porphyrite association" is seldom purely igneous, but commonly occurs as a mixture of igneous rocks and flysch, deep-sea chert, reefal limestone and other rock types, occurring in both mélanges and in less disrupted stratal successions.

In the Chinghiz-Tarbagatai the inital ?Vendian to Middle Cambrian submarine volcanism was tholeiitic in composition, but in the middle Cambrian changed to calc-alkalic, indicating a certain maturity of the island arc system that had developed on oceanic substrate (Mossakovsky & Dergunov 1985).

In the Cambrian and much of the Ordovician, the structural polarity of the Chinghiz-Tarbagatai system faced the northeast (present geographic coordinates) as shown by the dominant northeasterly vergence (Mossakovsky & Dergunov 1985). In the latest Ordovician to Silurian the polarity flipped (see Markova 1982, fig. 16, for a graphic depiction) and at the same time thick sequences of red to varicoloured sandstones, conglomerates, and argillites, with green rocks locally playing a significant part, began to be deposited to the southwest and south of the Cambro-Ordovician magmatic arc (e.g. Oroy, Karaaygyr ("black stallion"), Sulysor suites: Karyayev 1984). Farther north, in the Kalmyk-Kul (Kalmyk Lake) region, the middle late Ordovician flyschoid argillites, siltstones, and sandstones represent a typical forearc to the south of the Borovsk magmatic complex intruded into the Kökchetav Massif (Golovanov et al. 1969). Zonenshain et al. (1990, fig. 55) display a superb structural cross-section across the Chingiz Mountains, after Markova (1982, fig. 7), which shows all the hallmarks of a subduction-accretion complex.

There has been tremendous controversy in the Soviet geological literature as to whether these Ordovician-Silurian deposits belong to "geosynclinal flysch stages" or to "orogenic molasse stages"! The cause of the controversy is that in places these dominantly clastic sequences rest with important unconformities on older rocks, whereas in others the contacts are transitional. The sequences contain, in places, both terrestrial (redbeds) and marine sedimentary rocks, the latter displaying typical turbidite characteristics. Some authors have been unable to find any profound tectonic change between the so-called "geosynclinal" stages and the "molasse" stages in Central Kazakhstan: "According to the V.M. TSEISLER classification... this structural stage of Central Kazakhstan Caledonides represents its so-called molasse synclinoria, marked by a replacement of the geosynclinal complex by the molasse without a substantial structural remodeling, and also by a gradual replacement, going up the section, of marine deposits by the continental" (KARYAYEV 1984, p. 327).

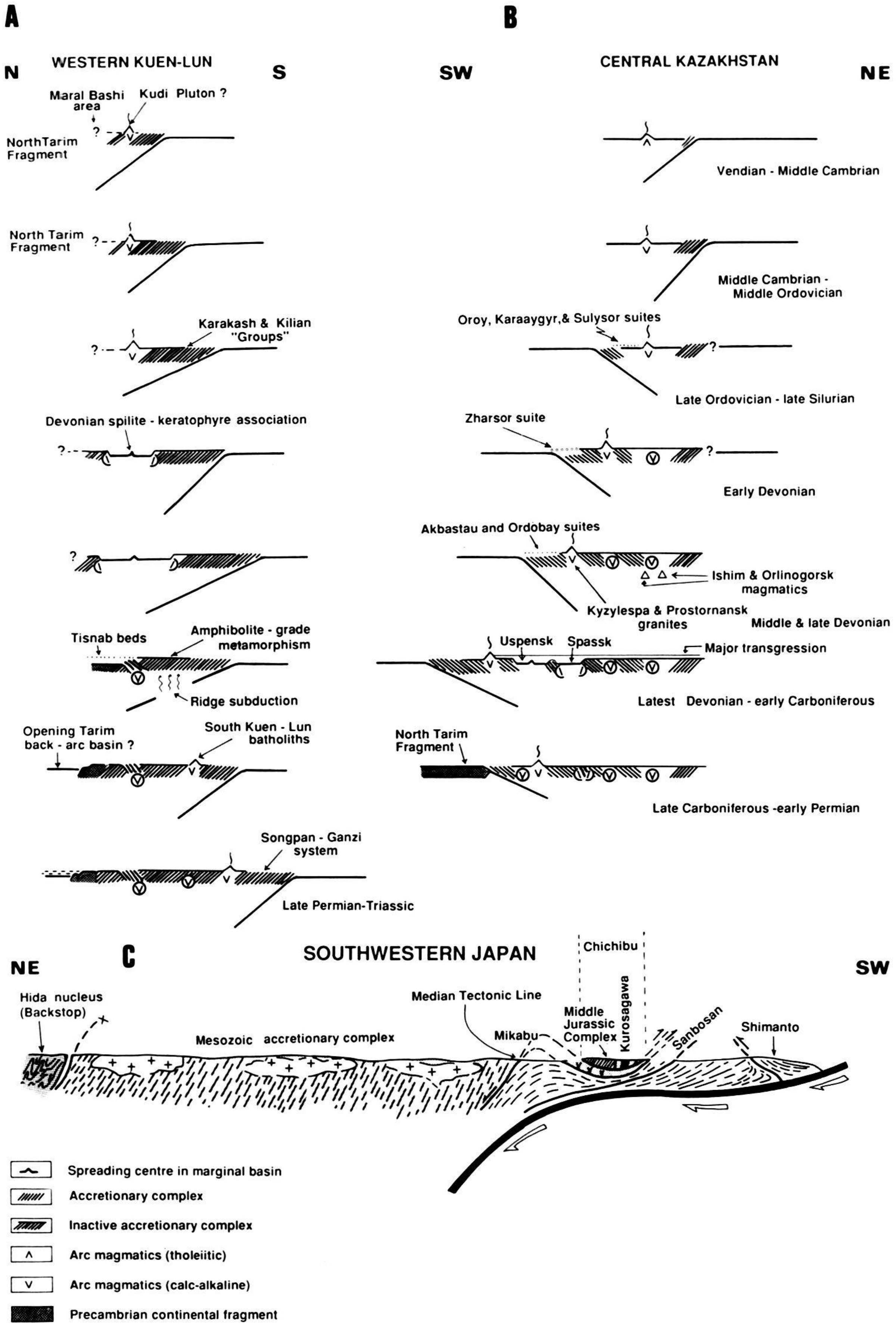
All these difficulties vanish when we view the so-called "molasse stage" in the early Palaeozoic sections in Central Kazakhstan as the expression of deposition in forearc and inner trench slope basins. This explains why in places the "molasse" is conformable on older deposits while in others it is sharply unconformable (inner trench slope *vs.* forearc deposition), why in some places it is subaerial, while in others it is submarine (outer high *vs.* submarine forearc deposition), and why no "substantial structural remodeling" takes place during the "molasse" time (because it too is a part of the growing accretionary complex). Major "synorogenic" batholiths (e.g. Zerenda, Krykkuduk, Chet, Borovsk) intruded while the so-called "molasse" deposition was going on and the "molasse" commonly does sit in prominent forearc positions on highly deformed "volcanic – sedimentary – siliceous deposits" in front of the arc intrusives (e.g. the Borovsk complex/Kalmyk-Kul forearc basin: GOLOVANOV et al. 1969, fig. 1). These intrusives are clearly arc-related and were intruded coevally with deposition in forearcs.

In the early Devonian, the arc magmatic axis invaded the former forearc areas and created new subduction-accretion complexes and forearcs in front of itself where "continental molasse and tephroid formation" (e.g. Zharsor suite: KARYAYEV 1984) was deposited. Through the middle and late Devonian the magmatic axis shifted farther to the south and southeast in the east and north, and northeast in the extreme southwestern part (KURCHAVOV 1985), and in the retroarc area alkalic volcanic and volcano-plutonic complexes (e.g. Ishim alkalic complex: Fig. 16) and even high-K granites (e.g. Orlinogorsk) originated, indicating that the production of continental crust through subduction-accretion and magmatism by the middle Devonian had reached a mature stage. The middle to late Devonian arc included the Kyzylespa and Prostornansk granites. In the foredeep, flysch, and in the forearc area shallower "molasse" deposition was characterized by such suites as Akbastau and Ordobay (KARYAYEV 1984).

In the latest Devonian to earliest Carboniferous interval the arc shifted still farther away from the back-arc area, where an extensional basin originated in the present-day Uspensk and Spassk zones that also coincided with a major marine transgression in Central Kazakhstan. The arc thus separated a partly epicontinental marine region in the back-arc area from a much deeper marine realm in the trench/forearc region. The

---

Fig. 17. Schematic sections illustrating the hypothesis outlined in this paper for the evolution of the Kuen-Lun (A) and the Kazakhstan Microcontinent (B). Both are compared with a schematic cross-section across southern Japan (C) from about Muroto-zaki to Toyama, which Şengör visited in 1988 under the guidance of Dr. Shigenori Maruyama.


A
N
WESTERN KUEN-LUN
S
Maral Bashi area
Kudi Pluton ?
NorthTarim Fragment
North Tarim Fragment
Karakash & Kilian "Groups"
Devonian spilite - keratophyre association
Tisnab beds
Amphibolite - grade metamorphism
Ridge subduction
Opening Tarim back - arc basin ?
South Kuen - Lun batholiths
Songpan - Ganzi system
Late Permian-Triassic
B
SW
CENTRAL KAZAKHSTAN
NE
Vendian - Middle Cambrian
Middle Cambrian - Middle Ordovician
Oroy, Karaaygyr,& Sulysor suites
Late Ordovician - late Silurian
Zharsor suite
Early Devonian
Akbastau and Ordobay suites
Ishim & Orlinogorsk magmatics
Kyzylespa & Prostornansk granites
Middle & late Devonian
Uspensk
Spassk
Major transgression
Latest Devonian - early Carboniferous
North Tarim Fragment
Late Carboniferous -early Permian
C
NE
SOUTHWESTERN JAPAN
SW
Chichibu
Hida nucleus (Backstop)
Mesozoic accretionary complex
Median Tectonic Line
Mikabu
Middle Jurassic Complex
Kurosagawa
Sanbosan
Shimanto
Spreading centre in marginal basin
Accretionary complex
Inactive accretionary complex
Arc magmatics (tholeiitic)
Arc magmatics (calc-alkaline)
Precambrian continental fragment

Balkash granitic complex intruded in the arc region, while both flysch and shallow water limestones, and terrestrial clastics were being deposited in the trench/forearc area (Karyayev 1984).

In the late Carboniferous-Permian interval the arc axis shifted only slightly back into the retroarc area, which might indicate imminent collision with a continent and/or another accretionary complex that might have foreshortened the forearc. Full-scale collision indeed was underway with the north Tarim-Tien Shan fragment by the later Permian which switched off arc magmatism and generated an areal, silicic alkalic to subalkalic magmatism associated with continental collision (e.g. the alaskites, alkalic granites, syenites and monzonites of the Bayanaul, Tluembet, Barkanas and Koytas igneous complexes: Karyayev 1984).

Fig. 17 summarizes the way in which the Central Kazakhstan "microcontinent" formed through the Palaeozoic, (for a partly different interpretation, see Markova 1982, fig. 15 and pp. 122ff) and compares it with the evolution of the Kuen-Lun/ Songpan-Ganzi system. A third object of comparison displays a present-day example of an accretionary complex, through which arc magmatism migrated during the Mesozoic-Cainozoic interval, namely Japan. In all three cases, the basic story is the same, namely the building out of subduction-accretion complexes in front of backstops of diverse nature and concurrently with the growth of the subduction-accretion complexes, the migration of magmatic arc axes across them in the direction of the ocean. In both the Kuen-Lun and in Kazakhstan, basins seem to have opened in the back-arc area (?back-arc basins) but later closed, before a terminal collision choked the subduction zone that governed the growth of the subduction-accretion complex. In Kazakhstan and in Japan metamorphism of the accretionary complex is mainly of greenschist grade, rising to amphibolite grade only near major plutons and in small relicts of older continental crust that have nothing to do with the metamorphism of the accretionary complex itself (Sobolev et al. 1982; Geological Atlas of Japan 1982). Only in the western Kuen-Lun we have encountered a widespread amphibolite-grade metamorphism that appears to have produced locally migmatites (Wyss 1940). This finds its analogue in the Chugach Mountains accretionary complex of Alaska and may have been related to ridge subduction (Plafker et al. 1989).

Fig. 10 shows the vast areas occupied by accretionary complexes in Asia implying that nearly all of the Altaid Asia formed through processes very similar to those we infer to have governed the evolution of the Kuen-Lun and the Central Kazakhstan ranges. In other words, the Turkic-Style orogeny dominated not only the northern part of the Cimmerides, but also most of the Altaid Asia. In the next section we discuss what this may mean for our understanding of continental growth and architecture.

7. Discussion

7.1 Tectonic analysis of Turkic-type orogens and the palaeotectonics of Central Asia

In the early days of plate tectonics, the Alps and the Himalaya coloured profoundly the popular image of collision-type orogenic belts, in which extremely narrow sutures essentially represented surfaces along which two colliding continents were apposed (cf. Gansser 1966, esp. p. 842; also Dewey & Bird 1970, figs. 2G, 11E, F, G and 13). By