IGCP-480 (for 2005-2009)
Structural and Tectonic Correlation across the Central Asia Orogenic Collage: Implications for Continental Growth and Intracontinental Deformation

Proposals

1. Introduction

The Central Asian orogenic belts occupy about 50% of northern Eurasia. They are bounded by the Angara (Siberian) and Russian cratons in the north and Tethysides in the south. Between the Russian and Angara cratons in the northwest, the Paleozoic and late Precambrian tectonic units of the Central Asian orogenic belts plunge westward beneath the thick Mesozoic and Cenozoic sedimentary fill of the vast Western Siberia Basin. Magnetic data indicate that these units can be traced as far north as the shore of the Arctic Ocean. The relationship between the Central Asian orogenic belts and Paleozoic fold belts of the Arctic regions has been a renewed subject of research in the past decades. Related to this problem is the tectonic history of the Western Siberian Basin that is rich in oil and gas resources and the structural origin of the enormous Siberian trap basalt. In the east, the Central Asian orogenic collage has a transitional boundary with the Nipponides. There, tectonic units of Central Asia experienced considerable rotation during the early Mesozoic subduction of the Paleo-Pacific Ocean. In the southwest, the Turan block is usually viewed as the limit of the Central Asian collage. However, geophysical data indicate the westward continuity of the Central Asian tectonic units to the Caucasus and perhaps farther west to the Hercynian belt of Europe. The sheer size of the Central Asian orogenic collage underscores its importance in understanding the evolution of the whole of Eurasia.

The hypotheses for the evolution of the Central Asia orogenic collage may be classified into two groups. The majority of researchers believe that the collage is made of numerous microcontinents and oceanic arcs that collided with one another and eventually accreted to the large continental nuclei - the Siberian, Russian, and North China cratons (Maruyama and Sakai, 1986; Zonenshain et al., 1990; Mossakovsky et al., 1993; Dobretsov et al., 1995; Golonka, 2000). This view is inspired by models of continent and arc-continent collision, which are ubiquitously considered as the most efficient mechanism of assembling a supercontinent. Indeed, these models work quite well in the Tethysides, Uralides, Variscides of central Europe and some other orogenic belts such as large parts of the Pan-African system in Gondwana-Land. The mosaic pattern and disposition of tectonic units in central Asia have been interpreted to favor this type of model. Numerous microcontinents imply the existence of a large volume of old continental crust in the Central Asian collage. The second type of model views the Central Asian collage to be made mainly of Paleozoic subduction-accretion materials (Şengör et al., 1993; Şengör and Natal'in, 1996a,b). These materials were accumulated against a few magmatic arcs of extended length whose evolution was characterized by long-distance and arc-parallel tectonic transport. This model is somewhat similar to the Mesozoic evolution of the North America Cordillera and predicts the existence of large orogen-parallel strike-slip faults.

The majority of continental blocks in Central Asia have crystalline basements, considered to be Precambrian in age. In places, this age has been confirmed by isotopic dating, but for many others the age determination was based on lithologic correlations and structural relationships with dated stratigraphic units or inferences concerning the tectonic history of the relevant regions. The latter approach has made the age assignment highly circular in reasoning. Employment of modern methods of isotopic dating has shown that previous age assessments of Precambrian basement are not always valid. In places, Precambrian gneisses have turned out to be Mesozoic in age or younger (e.g. Webb et al., 1999, Salnikova et al., 2001, Wilde et al., 2000). The original paleogeographic position of the continental blocks in Central Asia is also a subject of intense debate. Some researches argue that Gondwana-Land was the parent continent (Dobretsov, et al., 1995, Kheraskova et al., 1995, Wilde et al., 2000), while others infer exclusively a Siberian origin for the same blocks (Kuzmichev, 2001). Detrital zircon dating of extensively exposed flysch complexes in the region may help resolve this issue when combined with regional tectonic studies.

One of the most active research areas of modern tectonics is the investigation of the processes that are responsible for exhumation of high-pressure and ultrahigh-pressure metamorphic rocks. Central Asia is well-placed to address this question, as it exposes the deepest ultra-high-pressure rocks (Kokchetav massif) found so far. The solution of the problem may partly be related to the origin and evolution of the extensional structures in the region. More then 100 Precambrian to Cenozoic rifts are known in Northern Asia (Şengör and Natal'in, 2001). One of the largest mantle plumes may also be located there. Diversity of opinions on the origin of these structures persists.

During the last decade, geologists from various countries, working in international groups, have accomplished a tremendous amount of geologic work in northern Asia. These studies have dealt mainly with petrology, geochronology, stratigraphy, and mineral resources. These studies include limited amounts of discussion on the tectonic implications of the data and they in general lack a structural geological component. As a result, the structural setting of the rock units in question has often been poorly defined and the tectonic implications of the geochemical and petrologic data are difficult to interpret. It is therefore timely to call for international cooperative efforts that will facilitate the distribution of acquired data and expand the knowledge of major tectonic units and tectonic boundaries across the whole of the region.

2. Recent Tectonic Studies

Regional tectonic studies have been carried out in recent years in all countries that encompass the Central Asian orogenic collage. In Russia, principal research groups are based in Novosibirsk, Irkutsk, and Moscow. The Novosibirsk group has worked extensively in the Altay-Sayan region, as well as in surrounding areas in Kazakhstan and Mongolia. Their recent publications deal with Paleozoic evolution of the whole of Central Asia (Dobretsov, 1995; Berzin et al, 1994) and its neighboring regions (Buslov et al, 2000; Gibsher et al., 2000; Kazansky et al., 1998). Recently, tremendous progress has been achieved in determination of timing, petrogeneses, primary sources, and geodynamic significance of granitic plutons in the Altay-Sayan region (Shokalsky et al., 2000; Kruk et al., 1999; Vladimirov et al., 2001). The group works in cooperation with scientists from western countries and Japan on structural geology, tectonics, igneous petrology, and metamorphic geology of Siberia and Kazakhstan. The Irkutsk group has carried out similar researches in eastern Siberia and Mongolia (e.g. Sklyrov, 2001, Zorin, 1999). Recently-obtained paleomagnetic results impose important constraints on paleotectonic reconstruction of central Asia (Kravchinsky et al., 2001). Similar to the Novosibirsk group, Irkutsk geologists have close ties with geologists from USA, Mongolia, France and Japan. Geoscientists from various academic institutions in Moscow work on regional geology and tectonics of Central Asia (Burtman, 1999; Dergunov et al., 1997; Kheraskova et al., 1995, Khain et al., 1997; Kuzmichev, 2001, Ruzhentsev and Mossakovskiy, 1996, Fedorovsky et al., 1995), isotopic system and their tectonic implication (Kozakov et al., 1999, Kovalenko et al., 1999, Salnikova et al., 2001), and paleomagnetism and paleotectonic reconstructions (Bazhenov and Burtman, 1997; Bazhenov et al., 1999; Burtman, 1998; Didenko et al., 1994; Feinberg et al., 1996; Grishin et al., 1997).

In Kazakhstan, Uzbekistan, and Kyrgyzstan, tectonic and structural studies are mainly locally focused with few exceptions (e.g., Avdeev et al., 1997; Spiridovov et al., 1996). Results of these studies are published in local journals that are hardly accessible to the international geologic community. However, geoscientists from these states are active in various international projects including those that are run by UNESKO and IUGS (International Union of Geological Sciences). Although these projects mainly deal with mineral resources and petrology (e .g Bekzhanov et al., 1997), implications of tectonics and structural geology are also discussed in some of these publications. The recent achievement of geologists from central Asian states is the compilation of the Atlas of Lithology-Paleogeographical and Structural Maps of Central Eurasia at a scale of 1:2 000 000 (www.yugeo.nursat.kz). The atlas includes two structural maps and 43 palinspastic maps. Mongolian geoscientists have compiled the tectonic map of Mongolia (Dorjnamjaa et al., 1998). In cooperation with western scientists they published several important papers on Cenozoic deformation in Mongolia and various aspects of its Paleozoic evolution (e.g., Baljinnyam et al., 1993, Buchan et al., 2001).

Chinese geologists have long been working in the Chinese Altay (Niu et al., 1999; Jin et al., 1999; D. Wang et al., 1999; J. Wang et al., 1999; Liu et al., 1999; Dong and Zhang, 2000; Guo, 2000; Wei et al., 1997; Chen et al., 2001; Han et al., 1997, 1998, 1999) and its neighboring regions such as the Junggar basin (Gu et al., 1999; Xu et al., 2001), Tarim Basin (Gou et al., 2001), and the Tian Shan (Shu e al., 1999; Wang et al., 1999; Jun, 2000; Zhou et al., 2000; Li, 2001; Xiong et al., 2001; Xu et al., 2001; Zhang et al., 2001a, b; Liu, 2001). Despite a large amount of high-quality publications in recent years by the Chinese workers, these recent studies have mostly focused on the geochemistry of magmatism, mineral resources, and igneous and metamorphic petrology. Relatively little attention has been given to structural development of regional correlation of major tectonic boundaries with those outside China. It is interesting to note that several groups from various western countries have recently ventured into this relatively poorly studied area and emphasized Mesozoic and Cenozoic tectonics in the Chinese Altay and its neighboring regions. They include those from Great Britain (Buchan et al., 2001; Allen et al., 2001; Cunningham, 1998; Cunningham et al., 1996a and b), the US (Lamb and Badarch, 2000; Lamb et al., 1999; Hendrix et al., 1996; Webb et al., 1999), and France (Thomas et al., 1999a and b, Feinberg et al., Lemaire et al., 1998; Charvet et al., 2001). In addition, a German group has focused on petrology of magmatic rocks, mineral deposits and isotopic systems in application to crustal growth (Heinhorst et al, 2000). Cenozoic evolution of paleo-stress fields in the Baikal and Altay regions were investigated by geologists from Belgium and the Netherlands, in cooperation with Russian geologists based at Novosibirsk (Delvaux et al., 1995; 1997). A large amount of petrological, metamorphic and structural data was obtained by a group of Japanese geologists from Kazakhstan, Altay and Mongolia in recent years (e.g. Maruyama et al., 1999, Teraoka et al., 1996). These studies on the Cenozoic tectonic evolution of the region have resulted in recognizing major strike-slip faults in Mongolia, southern Russia, and Kazakhstan. Some of these faults have produced major earthquakes in the past two centuries. Many of the Cenozoic strike-slip faults have been reactivated from early Paleozoic faults.

A broad interest in the geology of Central Asia is evident from several on-going international projects. Among them IGCP–420 Project is the most closely connected to dealing with regional tectonics of the Central Asian orogenic collage. This project has already revealed that the main bulk of the continental crust in Central Asia is largely juvenile in nature. This result corroborates the suggestion that Phanerozoic subduction and accretion were mainly responsible for the crustal genesis of the Central Asian region (Şengör et al., 1993, Şengör and Natal'in, 1996a, 1996b).

3. Proposed Work

3.1. Frontal collision vs. strike-slip duplication of forearc during subduction. One of the major obstacles to understanding the tectonic evolution of Central Asia is the lack of structural information on major tectonic boundaries between postulated arcs and micro-continental blocks. Do they represent sutures characterized by thrust faulting and induced by final closure of oceans (e.g. Dobretsov et al., 1995) or zones of strike-slip faults originating from lateral translation of accreted materials in subduction complexes during subduction (e.g. Şengör and Natal'in, 1996)? Kinematic analysis of shear zones, isotopic dating of deformation events associated with the development of major tectonic boundaries and correlation of structural history and lithologic units will lead to a better palinspastic reconstruction and a more definitive test of the two end-member models outlined above.

3.2. Exhumation of high- (HP) to ultrahigh-pressure (UHP) metamorphic complexes. In the absence of reliable isotopic dating and detailed structural analysis, many metamorphic terranes in Central Asia were considered to be Precambrian in age and to represent the basement of micro-continents. However, recent studies show that some of the "Precambrian" gneisses were developed during Mesozoic extension via detachment faulting (Sklyarov et al., 1997, Webb et al., 1999) while others formed during Paleozoic subduction (Salnikova et al., 2001). Origin and exhumation of HP and UHP metamorphic rocks is another important aspect of our proposed tectonic studies of the Central Asian orogenic belts, as their tectonic settings remain poorly defined.

3.3. Tectonic setting of ophiolites and their significance for paleotectonic reconstructions. Recent studies of ophiolites in Central Asia (Buchan et al., 2001; Kröner et al., 2001; Pfänder et al., 2002; Robinson et al., 1999; Khain et al., 2003) have shown a great diversity in tectonic settings and ages. Şengör and Natal'in (in press) summarized available data and conclude that in the Altaids ophiolites are now encountered in three main settings: (1) ophiolites that occur as basement of ensimatic arcs, (2) ophiolites that occur in former forearcs now entrapped within transform sutures: (a) ophiolites as backstop to accretionary wedges, (b) ophirags within accretionary wedges and (3) Ophiolites in collisional suture zones that have usually evolved from members of the second category. Extremely complicated distribution of ophiolites is brought about by processes that shaped the Altaid edifice, namely, generation of supra-subduction zone forearc basements created by pre-arc spreading, back-arc basin opening, subduction-accretion, trench-linked strike-slip faulting including arc slicing and arc shaving faults and associated ocean floor spreading processes, and collision of buoyant pieces along suture zones. Without appreciating the nature and sequence of these processes and their superimposition, it is impossible to understand the rules that govern the distribution of oceanic basement fragments in the Altaids. Without apprehending of a tremendous degree of structural shuffling of previously distant environments and a large degree of dismembering of formerly more complete ocean floor fragments correct paleotectonic reconstructions are hardly possible. Closer cooperation of petrologists, structural geologists, and tectonicians is envisaged within the framework of this project.

3.4. Paleogeographic positions of tectonic units. The origin of many tectonic units in the Altaids and other orogenic systems in Central Asia is not well defined. Although some workers interpreted their origins to be derived from both Gondwana-Land and Laurasia (e.g. Keraskova et al., 1995), reasoning of these interpretations is usually rooted in gross correlation of stratigraphic successions and similar timing of events. No solid physical evidence such as correlating provenance of sedimentary sequences with potential cratonal sources has been obtained. Paleomagnetic studies are still limited to small areas or their results are often indecisive. The powerful method of dating detrital zircons has never been implemented. Identification of oceanic plateaus and seamounts in the Paleozoic orogenic collages of Central Asia is also limited in scope and geographic coverage. Neglecting their existence and role in creating collision-like deformation in the forearc and hinterland regions may have obscured the true history of ocean closure in the region.

3.5. Late Paleozoic and Mesozoic tectonics and the origin of large sedimentary basins. Huge sedimentary basins (Western Siberia, Junggar, and Turan) rich in oil and gas resources are located in Central Asia. Subsidence that affected areas of more than 10^6 km^2 still puzzled tectonicians working in the region. Paleozoic pre-basin history could have played a key role in determining the location and style of basin development. The relative role of deep mantle vs. plate-boundary processes in controlling basin development is a main research subject to be pursued by this project. Numerous small Mesozoic and Cenozoic fault-bounded sedimentary basins form an intricate pattern both concordant and discordant to the early Paleozoic regional fabric. These basins are often treated as rifts or pull-apart basins (Şengör and Natal'in, 2001). However, a detailed structural analysis of basin-bounding faults will serve to test existing tectonic models.

3.6. Far-Field Effect of Indo-Asian Collision. Indo-Asian collision in the past 60-70 Myr has reshaped the tectonic framework of the whole of Asia by large-scale strike-slip faulting and continental subduction (Molnar and Tapponnier, 1975; Meyer et al., 1998; Tapponnier et al., 2001). Burchfiel and Royden (1991) suggested that the topography of Asia from the Arctic ocean to the Himalayan front was created in the Tertiary. How the deformation within Asia was induced by subduction along the Pacific Ocean in the east and collision between India and Asia in the south has been the subject of extensive speculations based on geodynamic modeling (England and Houseman, 1988; Kong and Bird, 1996). However, field tests of the model predictions have been lacking, particularly in the Central Asia region. For example, how and why the Baikal rift was initiated in the Cenozoic remains a poorly resolved but important tectonic problem. Recent studies have emphasized the similarities between the well-known north-south trending rifts in Tibet to those in North China and southeast Siberia (Yin and Harrison, 2000; Yin, 2000). It has also been proposed that Cenozoic east-west extension is widespread in Mongolia (Cunningham, 2001). This mode of deformation is very similar to that in Tibet but is drastically different from isolated rifts like the Shanxi graben and Baikal rift. Geologic investigations of Cenozoic extensional structures and related large-scale strike-slip faults in Central Asia will provide new insights into the physical processes of intracontinental deformation over a vast area during combined continent-continent collision and oceanic subduction. Our proposed work will focus on the initiation age, rate, kinematics, and distribution of Cenozoic faults in Central Asia. Geometrical and kinematic links of Central Asian faults with those in other parts of the Indo-Asian collision will also be explored.

3.7. Mantle plumes. The identification of plumes and their role in tectonic processes is a hot topic of current tectonic researches (e.g. Ernst and Buchan, 2001). The repeated activity of mantle superplumes in Northern Asia has been suggested by Yarmolyuk et al (1995, 1998, 2000), Kovalenko et al (1999) and Dobretsov (2002). This activity resulted in the formation of voluminous Devonian basalts in the Vilyuy province of the Angaran craton and the famous Permo-Triassic Siberian trapps. Most of intraplate tectonic processes may be related to the Siberian superplume. The recognition of mantle plume influence on the tectonic evolution of folded areas surrounding the Angaran craton is an interesting and important subject for cooperative research within this project.

4. Results expected of the project

a) Theoretical sciences.

The main contribution expected from this project is the expected corroboration of the role of strike-slip stacking of magmatic arc and accretionary forearc complexes. These build large area of continental crust formed from coevally evolved arc/forearc units. In the Precambrian, large areas of continental crust, in certain well-defined regions, appear to have formed in very limited time intervals (100-500 Ma duration). Processes forming such areas have been claimed not to have operate in Phanerozoic. This has led to non-uniformitarian models of crust generation in Precambrian. Preliminary syntheses and subsequent corroborative data gathering have shown, by contrast, that the Altaids, which have evolved from about 600 Ma to 150 Ma, are just such a region of crust generation.

Strike-slip regimes are complex. They not only form very long, straight and/or gently arcuate zones of lateral displacement, but changes of strike along them form nuclei of extensional and compressional tectonics. Basins of diverse shape and characteristics with accompaying magmatic and metamorphic events and small orogens, resembling Transverse Range along the San Andreas System in California, result from this activity and contribute to the secondary structuration of the continental crust. Spectacular example of such structure are known within the Altaids and understanding of their tectonics is expected to illuminate the history of many complex structures in older, less well-exposed Turkic-type orogens and thus contribute to a more detailed understanding of the architecture of the continental crust.

An important result of the proposed study concerns structural reactivation of continental crust. The Altaids are not only an early Phanerozoic orogenic complex, but one, which was repeatedly deformed as a consequence of the subduction and collision events that took place to their south throughout the Mesozoic and Cenozoic. Many Altaid structures, but particularly the large strike-slip faults and the basins became reactivated many times. There is also a close correlation between Altaid structures and the distribution of seismicity. The Altaids thus represent an ideal laboratory to study reactivation.

b) Applied sciences and technology

This project is not aimed at solutions of problems in any branch of applied science. It is, however, inevitable that its result constitute a major aid to petroleum and mineral exploration and environmental sciences.

Some of the world's richest hydrocarbon reserves are found in basins that resulted from the Altaid evolution. The West Siberian Basin, the Junggar and the Tarim are the largest of these. An improved understanding of their structure and tectonic evolution will naturally lead to better exploration policies in them.

The mineral richness of the Altaids is legendary. The fabulous wealth of the Demidoff family in Czarist Russia derived mostly from platinum, gold and silver mines of the Ural and Altay. Since then many other mineral localities have been found and explored. These mines are located in certain tectonic niches and are mostly structurally controlled. An improved understanding of the structure and tectonic evolution of the Altaids will lead to healthier prediction of especially subsurface occurrences. Both earthquake hazard assessment and the behavior of Quaternary lake basins can be better understand once the location and behavior of the reactivated Altaid structures are better known.

c) Benefits to society

See item (b) above.

5. Proposed mode and plan of work

The project is envisaged to bring together scientists active in theoretical research with those working in the field. This will be accomplished by means of workshops accompanied with field excursions to be held in critical areas in Central Asia. Such format will help integrate the field work being carried out in developing countries of Central Asia with the models developed by geologists, geochemists, and geophysicists in the west and in Japan. There are already a number of projects being carried out by the proposed participants of our IGCP Project. Our project will coordinate and integrate these into a comprehensive model that is expected to evolve during the workshops and the excursions.

We hope to publish the proceedings of the workshops as special issues in internationally respected, referred journals. We also plan to publish guide-books for evry excursion in book format, hopefully by a publisher international repute and established market. There is a little doubt that such excursion guide-books will constitute significant contribution to the literature of hitherto little-known areas by international community.

Our proposed plan was used during the IGCP Project 420 with great success. We hope to do better than that by using the experience gathered during that project.

6. Proposed Workshops:

We propose 5 meetings during the 5-year project period. All meetings will combine scientific presentation and discussion (2 days) with field excursions (3 to 5 days). Each meeting will be scheduled to last no more than a week. The main theme of each conference will focus on understanding of a cross-strike tectonic transect across the Central Asian orogenic belts. This will be done systematically from north to south and from west to east. A tentative schedule is as follows:

2004: Olkhon (Lake Baikal), Irkutsk, Russia.
2005: Central or eastern Kazakhstan (Almaa-Aty, Ust Kamenogorsk)
2006: Southern Mongolia, Ulaanbaatar, Mongolia.
2007: Chinese Altay, Urumuqi, China.
2008: Russian far-east.

8. References

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