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The Cretaceous in Gyangze, Southern Xizang (Tibet): Revised

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The stratigraphic sequence, framework and thickness of the abyssal-bathyal Cretaceous in Gyangze, the northern Tethyan Himalayas, South Xizang (Tibet), are revised in this paper. It is proposed that the Jiabula Formation, Chuangde Formation and Zongzhuo Formation constitute the Cretaceous in this area, in which their sequences, ages and thicknesses are distinctively different from the previous ones. The Jiabula Formation, aged from Berriasian to Santonian, is composed of black shale with intercalated turbiditic sandstone, lenticular limestone and pyrite nodules, and it can be subdivided into two members "White Member" and "Black Member". The Chuangde Formation, consisting of purplish red marlstone and mudstone with some foraminiferal and radiolarian fossils, belongs to the Early-Middle Campanian. The Zongzhuo Formation, the famous "Beijia Olistostrome", was deposited in the Late Campanian-Maastrichtian, and is dominated by black-grey shale with a large amount of olistoliths composed of sandstone, limestone and siliceous rocks. The lithostratigraphical units proposed here are readily correlated in the Gyangze area by some marks such as colourness and lithology. The Cretaceous thickness is determined to be between 300 and 700 m, rather than 2000 m or more than 3000 m as given by previous workers. It is proposed here that the formation stratotype should be changed to the Chuangde section.

Key words: Jiabula Formation; Chuangde Formation; Zongzhuo Formation; Cretaceous; Gyangze; South Xizang (Tibet)

Division of Quaternary Lacustrine Beds in Jing'erwa Borehole of the Yangyuan Basin

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By means of various methods, the writers analyzed cores from a borehole, 200.6 m deep, in the Yanyuan basin. In terms of lithostratigraphic, biologic and paleomagnetic features, the Quaternary lacustrine sediments were renamed the Yanyuan Group, which can be divided into three formations. The Lower Pleistocene Nihewan Formation (in depth of 200.6–107.8 m), not reaching the bottom of the formation) consists of brown-gray silty clay and silt. The Middle-Lower Pleistocene Xiaodukou Formation (in depth of 107.8–20.6 m) consists mainly of gray and grayish-black silty clay and fine sands. Varves are the marker beds in this Formation. The bottom boundary of the Xiaodukou Formation is 1000 ka B.P. in age. The Upper-Middle Pleistocene Jing'erwa Formation (in depth of 20.6–0 m), newly named in this paper, consists of greenish-yellow silt and silty clay. The age of the bottom boundary is approximately 200 ka B.P. and that of the top is about 10 ka B.P.

Key words: Yanyuan Group; Jing'erwa Formation; stratigraphic division; Hebei Province

Palaeoproterozoic Eucaryotic Fossils from North China

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A number of microplants with spherical, triangular, polyangular and boat-like shapes have been found from both the early Palaeoproterozoic Dashiling and Qingshicun Formations (ca. 2500–2400 Ma) of the Doucun Subgroup of the Hutuo Group and the late Palaeoproterozoic Changzhougou and Chuanlinggou Formations (ca. 1800–1700 Ma) of the Changcheng Group in North China. According to the features of these fossils, such as size, external shape and internal structure, they may belong to unicellular eucaryotic planktons. These data indicate that the earliest unicellular encaryotes on the Earth might have appearred in the lower Hutuo Group (ca. 2500–2400 Ma) of the early Palaeoproterozoic and were rather prosperous to the late Palaeoproterozoic Changcheng Group (ca. 1800–1700 Ma). For this reason, the geological records of eucaryotes may be moved up to 2500–2400 Ma from 1800–1700 Ma.

Key words: Eucaryotic fossils; Palaeoproterozoic; North China

Tectonic Characteristics and Petroleum Prospects of Cenozoic Compound Rejuvenated Foreland Basins in Tarim

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The term "rejuvenated foreland basin" is proposed in view of the geological features of China, which is the third important type of foreland basins. The other two are the peripheral foreland and back-arc foreland basins. This type of basins belongs to the internal structure of a continental plate. With the new concept explained, this paper discusses in detail the basic structural features and deformation styles as well as favourable conditions and prospects for oil and gas in the basins by taking the Cenozoic compound rejuvenated foreland basins in Tarim as an example. This may provide guidance for oil and gas exploration in the new type of basins in Tarim and relevant basins in western China. It could be concluded as follows: ① the Kuqa and southwest Tarim rejuvenated foreland basins are formed in front of the Tianshan and Kunlun Mountains since Cenozoic, both are typical rejuvenated foreland basins compounded on a plane. Their formation is mainly related to the early structural traces such as palaeo-A subduction existing in the southern margin of basins during Silurian to Devonian and Triassic and the northern margin during Permian, and also the collision between the India and Eurasia plates and their continuous movement. It is a long-distance effect of the collision that resulted in the revival and regeneration of the palaeo-A type subduction in Tarim in the early time. ② The evolution of Cenozoic rejuvenated foreland basins in Tarim could be divided into four stages: The first is the development stage of pre-rejuvenated foreland basins during the Palaeocene and Eocene as well as the early Tertiary. The second is the early stage of rejuvenated foreland basins from Oligocene to late Tertiary. The third is the development stage of rejuvenated foreland basins from Kangcun age to Kuqa age in late Tertiary, and the forth is the structurally deformation stage from the end of Kangcun age to the early Pleistocene. ③ The structural deformation styles of rejuvenated foreland basins in Tarim are characterized by rejuvenated foreland thrust belts, frontal uplifting and structures related to strike-slip and other activities. Among them, the rejuvenated foreland thrust belts include the Kuqa, southwest Tarim and Kalpin thrust belts, which are all Meso-Cenozoic complex structural belts of faults and folds.④ The rejuvenated foreland basins in Tarim have favourable conditions for oil and gas. The source rocks are coalbeds and lacustrine mudstones developed in Mesozoic sequences of rejuvenated foreland basins, and the reservoirs are found not only in sequences of pre-rejuvenated foreland basins, but also in the rejuvenated foreland basins. They are mainly sandbodies of great thickness of fluvial and shallow lacustrine facies. Two regional caprocks are deposited in Jurassic coalbeds and lower Tertiary gypsiferous-saline rocks. In recent years, a great deal of progress has been made in natural gas exploration in rejuvenated foreland basins in Tarim, and a large quantity of natural gas reserves have been proved and a number of large-medium gas fields discovered, which demonstrate the good potential for oil and gas exploration in rejuvenated foreland basins in Tarim.
Key words: rejuvenated foreland basin; Tarim; Neogene to Quaternary; structural-depositional evolution; rejuvenated foreland thrust belt; petroleum geology

Structural Styles of the Foreland Fold and Thrust Belt in the Tianshuihai Area, Western Kunlun, and its Tectonic Evolution

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Applying the theory of collision orogenic tectonic facies, the authors investigated the Triassic sedimentary characteristics and its tectonic environment in the Tianshuihai area, and also researched the structural style and its evolution in the foreland fold and thrust belt caused by the collision between the Qiangtang terrane and the Tarim plate in the late Triassic. By analyzing the chemical components and sedimentary characteristics of the strata, the authors conclude that the sediment is a set of typical deep-water to semi-deep-water flysch formed in a passive continental margin. In the light of deformational characteristics, the foreland fold and thrust belt can be divided into five zones from NE to SW, i.e.: the trailing edge zone, root zone, central zone, front zone and edge zone. From NE to SW, the deformation becomes weaker progressively. The thrusting trend is high-angle thrusts associations. And the characteristics of the fold style is SW-inverted fold to board fold along the NE-SW direction. Based on the above discussion, the authors put forward an evolutionary model of the foreland fold and thrust belt in the Tianshuihai area: Before the end of Triassic, the area was a passive continental margin in the north of Qiangtang block. In the end of late Triassic, this block collided with the south margin of Tarim plate. From the end of Triassic to early Jurassic, the sedimentation in the passive continental margin ceased and this area entered an evolution stage of thrusting, folding, uplifting to form a foreland basin because of the collision between the block and the late Paleozoic-early Mesozic island arc on the south of the Tarim plate.
Key words: western Kunlun Mountains; foreland fold and thrust belt; passive continental margin; imbricate fan; duplex

The Study on Petrology, Mineralogy and Geochemistry of Tungsten-bearing Granitic Rocks in the Yeniutan, Subei County, Gansu Province

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The Yeniutan granodiorite intrustion with an age of 460 Ma is spatially and temporally associated with the Ta'ergou tungsten deposit, one of the recently discovered and explored large tungsten resources in northwest China. It is located in the North Qilian Caledonian belt and consists of a granodiorite main phase cut by biotite granite dikes. The country rocks are the Early Proterozoic Beidahe Group and Ordovician volcanic rocks which are overprinted by a 500–800 m wide thermal metamorphic aureole. The granodiorite has coarse-grained and pseudoporphyritic texture and is composed of variable amounts of amphibole, pyroxene, biotite, plagioclase, quartz and alkali feldspar perthite. Accessory minerals are sphene, magnetite, zircon, apatite and allanite. The biotite granite is fine- to medium-grained, and is composed of plagioclase, K-feldspar, quartz and biotite with accessory apatite, zircon and thorite.

The SiO_2 content of the granodiorite ranges 57%–63 %, the Al index (Na+K/Al) varies from 0.43 to 0.58. The SiO_2 content of biotite granite ranges from 65%–66% and its Al index varies from 0.43 to 0.58. The two granitic rocks share similar characteristics of trace elements and rare earth elements. Their contents of compatible components such as V, Ba, Co, Ni, Cr and Sr are high, the Rb content ranges from 20×10^{-6} to 188×10^{-6}, and their Rb/Sr ratios are mainly in between 0.3 and 0.6. The REE content of the granodiorite ranges 141×10^{-6}–241×10^{-6}, the La/Yb ratio varies from 10 to 31, δEu from 0.6 to 0.8. The total amount of the REE contents of the biotite granite is about 160×10^{-6}, the La/Yb ratio varies from 19 to 36, and δEu from 0.5 to 0.9. All geochemical indicators reflect an evolution from pseudoporphyritic granodiorite to biotite granite at a generally low degree of fractionation.

Sr isotope data indicate a high degree of contamination and assimilationin the upper crust. Unlike most tungsten granite suites in which the latest intrusive unit is genetically associated with tungsten mineralization, the main-phase granodiorite of the Yeniutan intrusion is related to tungsten mineralization. Compared to the regional geological evolution and in the light of geochemical and isotope data the Yeniutan granodiorite and its related tungsten mineralization are deduced to have formed in a pre-collisional rather than a collisional setting.

Key words: tungsten granitic rock; petrology; geochemistry; Yeniutan; Gansu Province

Discovery of Eclogite in Dulan, Qinghai Province and Its Significance for Studying the HP—UHP Metamorphic Belt along the Central Orogenic Belt of China

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Eclogite was found in the Proterozoic gneiss about 40 km northeast of the Dulan town, Qinghai Province. It occurs as pods in the gneisses of the Proterozoic Shaliuhe Group, forming an EW trending composite belt composed of a northern sub-belt about 10 km wide and a southern one 3–5 km wide. The peak metamorphic minerals in the eclogites of the northern belt are garnet-omphacite-phengite-rutile and retrograded minerals are mainly amphibole and some high-Na feldspar. In the southern belt the peak metamorphic minerals are garnet-omphacite-rutile-kyanite-zoisite (?), and the retrograded minerals are characterized by the appearance of a large amount of feldspar-amphibole-zoisite-quartz. The compositions of garnets are different in the two belts, 38%–54% almandine, 21%–24% grossular and 19%–37% pyrope molecules in the southern belt and 41%–58%, 13%–38% and 10%–27% in the northern belt, respectively. Grt-Omp geothermometer calculation (using the method by Krogh, 1988) yields a temperature range of 652–698°C at the pressure of 2.0 GPa for the northern belt eclogite and 873–913°C for the southern belt. The peak pressure of 2.0–2.6 GPa for the northern belt by using Grt-Ph geobarometer, and >2.0 GPa for the south belt, by estimation of the mineral assemblage Grt-Omp-Ky without paragonite. The petrological and mineralogical features and *p-t* conditions of the Dulan eclogite and their country rocks are very similar to those of the Da Qaidam eclogites and the Altun eclogites, suggesting that they together constitute an Early Palaeozoic high pressure metamorphic belt, probably connecting eastward with the Early Palaeozoic eclogites in the northern Qinling, Tongbo, and northern Dabie, forming a huge HP-UHP metamorphic belt extending from west to east across the central continent of China, and may represent an old boundary between the south China plate and the north China plate.

Key words: HP metamorphic belt; eclogite; Dulan; north margin of the Qaidam basin

Carbon and Oxygen Isotope Compositions of Ore-bearing Dolostone in the Bayan Obo Deposit as Well as Two Typical Micrite Mounds and a Carbonatite Dyke

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To study the genesis of the orebearing dolostone, one of the key problems of the genesis of the famous Bayan Obo deposit, the writers determine and compare the carbon and oxygen isotope compositions of dolomite and calcite of the ore-bearing dolostone with those of two micrite mounds and a carbonatite dyke.

The micrite mound at the top of the Cambro—Ordovician Sailinhuodong Group, in Heinaobao, about 25 km southeast of Bayan Obo, and the micrite mound of the Upper Cambrian in Jiu Yuan, the Western Hills, Beijing, show the $\delta^{13}C$ values of 0 $\pm$2‰ and $\delta^{18}O$ values of 18.3‰ to 25.1‰, indicating normal marine precipitation. Oxygen isotope fractionations between dolomite and calcite in the micrite mounds from Heinaobao are in disequilibrium, indicating dolomitization of limestone during the diagenesis.

Profile-sampling was carried out for carbonates in the Bayan Obo orefield. Carbon and oxygen isotope analyses show that the dolostones within the East Mine and at the eastern end and western end of the orebearing dolostone belt have similar $\delta^{13}C$ and $\delta^{18}O$ ranges. The dolostones within the East Mine have $\delta^{13}C$ of −7.9‰ to −1.1‰ and $\delta^{18}O$ of 9.1‰ to 20.9‰; the dolostones at the two ends have $\delta^{13}C$ of −7.9‰ to −0.6‰ and $\delta^{18}O$ of 8.6‰ to 25.7‰. Carbon and oxygen isotope fractionations ($\Delta^{13}C$ and $\Delta^{18}O$) between dolomite and calcite in the orebearing dolostone from a part of the samples have $\Delta^{13}C$ and $\Delta^{18}O$ values with both less than 0‰, indicating the influence of secondary alteration. A number of low $\delta^{18}O$ dolomite also has negative $\Delta^{18}O$ values, indicating the intensive alteration by mantle-derived magnesium-rich fluids to sedimentary carbonates.

A carbonatite dyke northeast 3 km northeast of the East Mine, intruded in H_2 sandstone, has a small range of isotopic variation: $\delta^{13}C$ varies from −7.2‰ to −4.7‰, being similar to the normal mantle; $\delta^{18}O$ varies from 11.9‰ to 16.4‰, being significantly higher than the $\delta^{18}O$ of the mantle (5.7‰ $\pm$ 1.0‰), indicating that the sedimentary carbonate was carried into the mantle by plate subduction to form ^{18}O-rich carbonatite magma via mixing and melting at high temperatures and pressures. Both carbon and oxygen isotope fractionations between dolomite and calcite from the carbonatite dyke are less than 0‰, being in conflict with the sequence of ^{13}C- and ^{18}O-enrichment in dolomite, relative to calcite at thermodynamic equilibrium. Thus, the disequilibrium dolomite-calcite pairs are not cogenetic, and at least one of them is of secondary origin. This implies that the carbonatite dyke underwent hydrothermal alteration subsequent to its emplacement.

The present studies suggest that the dolostone in the Bayan Obo ore district would result from metasomatism by mantle-derived fluids of the sedimentary carbonates. It is concluded that the carbonates of the micrite mounds underwent the metasomatism by mantle-derived fluids which were extremely rich in REE and some other elements, resulting in the formation of the superlarge Fe-Nb-REE ore deposit in Bayan Obo. The large variation in both $\delta^{13}C$ and $\delta^{18}O$ values of the ore-bearing dolostone are ascribed to the heterogeneous metasomatism by the mantle-derived fluid of the sedimentary carbonates.

Key words: REE-Niobium-iron deposit; dolostone; micrite mound; carbon isotopes; oxygen isotopes; mantle fluid; metasomatism; Bayan Obo; Inner Mongolia

Study on Rb-Sr Isotopic Ages of Gold Deposits in West Junggar Area, Xinjiang

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As one of the most important gold mineralization provinces, in Xinjiang, the West Junggar region is rich in gold resources with more than 10 deposits of different scales and hundreds of mineralized occurrences. Veined, stockwork and alteration-sheathed gold ores have been found in the area, belonging to four genetic types: the volcanic hydrothermal ores related to early-middle Carboniferous volcanism; subvolcanic hydrothermal ores related to intermediate-acidic porphyry intrusions; hydrothermal ores to the granitic intrusion and dynamo-hydrothermal ores related to regional dynamic metamorphism along the faults. Study of isotopic geochronology of mineralization and correlative geological events shows that these gold deposits were formed in a post-collision tectonic environment and four mineralization stages can be distinguished: the early Carboniferous (340 Ma ±), middle Carboniferous (310 Ma ±), late Carboniferous (290 Ma ±) and early Permian (270 Ma ±).