

## Calculating of soil carbon storage of China based on multi-purpose geochemical survey

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Soil carbon storage is an important parameter for the study of carbon circling and global change. Accurate calculation of this parameter is limited by data sources for a long time. Multi-purpose geochemical survey (MPGS) in China, covering 1.6 million km<sup>2</sup> by 2008, using a scheme of grid sampling (one sample per km<sup>2</sup> and mixed analysis each 4km<sup>2</sup>) with double layers (surface 0-20cm and deep layer 150-180 cm), provides large quantities of data for soil carbon storage calculation.

We have been calculating organic carbon storage of China using data from MPGS. A concept of "Unit Soil Carbon Amount (USCA)", defining as the amount (weight) of carbon storage in the MPGS unit area (4km<sup>2</sup>), was put forward as the basic unit to be cumulated. On the basis of 414 soil profiles from 14 provinces, it was found that soil organic carbon (TOC), has a trend of exponential decreasing with depth. Thus, USCA<sub>TOC</sub> was calculated for each MPGS unit area by integration of the exponential model that is determined by the surface and deep TOC contents:

$$USCA_{TOC} = \left\{ \frac{(TOC_1 - TOC_2) \cdot [(d_1 - d_3) + d_3 \cdot (\ln d_3 - \ln d_2)]}{\ln d_1 - \ln d_2} + TOC_2 \cdot d_3 \right\} \times \rho \times 4$$

where, TOC<sub>1</sub> and TOC<sub>2</sub> denote TOC in surface and deep layer respectively; d<sub>1</sub> and d<sub>2</sub> is the depth of the two layers; d<sub>3</sub> is the lower limit for integration and 1m was taken; ρ is the soil bulk density.

The results, calculated in the MPGS regions by 2008, showed that soil types and land use are the main factors that determine USCA<sub>TOC</sub> or soil organic carbon density (SOCD). By soil types, meadow soil and chestnut soil have highest SOCD of 69879 t/km<sup>2</sup> and 34583 t/km<sup>2</sup> respectively, and coastal sand soil have lowest SOCD of 3906 t/km<sup>2</sup>. By land use type, forestry and grass land have highest SOCD of 28323 t/km<sup>2</sup> and 27126 t/km<sup>2</sup> respectively, and residential area have lowest SOCD of 15558 t/km<sup>2</sup>.

## The rare earth element characteristics of the silicolite of Early Cambrian barite deposits in East Guizhou, China

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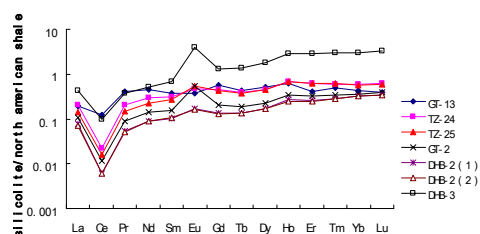
### Geological Setting

The Lower Cambrian black shale sequence of the Niutitang Fm. in southeast Guizhou China hosts a barite layer. The ore-bearing rock series is composed of black silicolite, carbonaceous shale interbedded with phosphorite, barite and carbonaceous shale in ascending sequence. The stratified main ore bodies, are dominantly embodied in the silicolite and black shale of the lower section of the Niutitang Fm. of the early Cambrian.

### Discussion of Results

Systematical silicolite samplings for the analysis of rare earth element by atomic emission spectrometry were taken in the Dahebian barite deposit in Tianzhu County of Guizhou Province China. Samples of silicolite were analyzed in the State Key Laboratory for Mineral Deposits Research.

Based on the analysis of rare earth element by atomic emission spectrometry, the characteristics was reported for the silicolite of barite deposits (Fig 1). The study provides evidence for the submarine hydrothermal exhalative genesis of Dahebian and Xinhuan barite deposits.



**Figure 1:** The NAAS-normalized rare earth element patterns for silicolite.

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## The characteristics of trace elements in Emeishan basalt and its contribution to mineralization

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Emeishan basalt (EB) related mantle plume, Permian basic volcanic rocks belonging to the continent flood basalt, widely occurs in southwestern China, and has been extensively studied [1, 2, 3]. EB consists of four lithologic sections from bottom to up: the first consists of volcanic breccia; the second consists of porphyritic basalt, the third consists of amygdaloidal basalt and compact massive basalt; and the last consists of compact massive basalt and amygdaloidal basalt. The trace elements from 102 EB samples in the southern part of the eastern Yunnan province, China, were obtained. The results show that (1) Pt, Pd, Au and Cu are 10.2ng/g, 9.7ng/g, 5.2ng/g, and 314.3ug/g, respectively, which are higher than that of in the original upper mantle; (2) compared with the northern of the study area, Pt and Pd have enrichment trends, and (3) compared with the abundance of continental crust, the enrichment sequence is Pt-Pd-Cu-V-Ag-Au-Zn-Co-F. Cu mineralization associated with zeolitization, actinolite-tremolitization, silicatization, bituminization mainly occur in the last lithologic section with Pt-10.1ng/g, Pd-11.3ng/g, Au-5.3ng/g, Cu-444.2ug/g, which is like as the Keweenaw copper deposit, and Au mineralization mainly occurs in the tuff. The results also demonstrate that mantle plume control the spatial distribution of EB, which offers the ore-forming materials for related Cu, Au mineralization.

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## Geochronology and geochemistry of Triassic Sanyanlong granitic complex in Eastern Tibetan Plateau: Origin and implications for tectonic evolution

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Zircon U-Pb dating by LA-ICP-MS and geochemical study have been conducted on the Late Triassic Sanyanlong granitic complex, eastern Tibetan Plateau. This granitic complex is the biggest intrusion in the Songpan-Garzê Fold Belt (SGFB), formed at 210 Ma, 10-15Myr younger than those exposed to the east [1-2] and north [3]. This complex composed of two major rock types: one is high-K calc-alkaline rocks with adakitic affinities (K-adakites), with Sr > 550 ppm, Y < 12 ppm, strongly fractionated rare earth element (REE) patterns ((La/Yb)<sub>N</sub> = 53-86) and high K<sub>2</sub>O/Na<sub>2</sub>O (≈ 1); another is ordinary high-K calcalkaline I-types with lower Sr (< 400 ppm), higher Y (> 20 ppm) and weakly fractionated REE patterns ((La/Yb)<sub>N</sub> < 20). The K-adakites have weaker negative Eu anomalies (Eu/Eu\* = 0.62 to 0.81) than ordinary rocks (Eu/Eu\* = 0.48 to 0.78). These geochemical features are generally consistent with those older eastern granitoids [1-3]. The K-adakites are interpreted as magmas were derived through partial melting of thickened and then delaminated TTG-type, eclogitic lower crust, with some contribution from juvenile enriched mantle melts. Ordinary high-K calcalkaline magmas were generated by partial melting of shallower lower crustal rocks. These new data argue that magmatism in the SGFB last over 20 Myr (230-210Ma) and further imply that the passive margin crust of the Songpan Ocean was greatly thickened and then delaminated, all within a time interval of ~ 30 Myr. Such post-collisional crustal thickening could be the tectonic setting for the generation of many adakitic magmas.

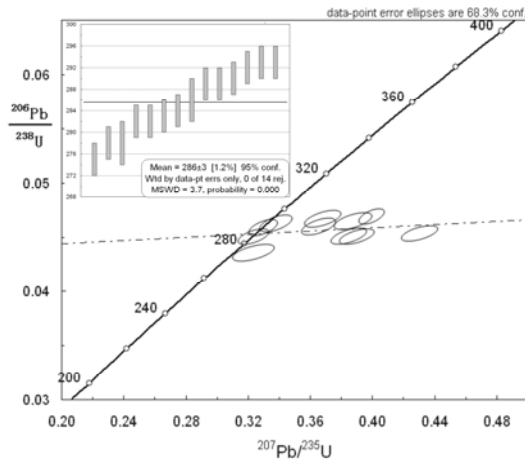
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## Redefinition of age for the volcanic rocks from Xiaocaohu, Beishan, Gansu Province China

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The volcanic rocks from Xiaocaohu of Beishan, Gansu Province, previously considered as 'Xiaocaohu rock', are bimodal volcanic rocks assemblage experienced ductile deformation. It is extent in NWW-direction and bounded by Dunhuan Group to the south as ductile fault. Geochemically, the basic rocks and acid are the calc-alkaline series, with  $\sigma < 4$  (1.42-3.05), and showing 47.13-59.5%, 70.81-76.53%  $\text{SiO}_2$  respectively. All the rocks characterized by distinct enrichment in LREE and have the pattern similarity to the tholeiite from continent rift. LA-ICP-MS dating on the zircons from dacite yielded  $286 \pm 3$  Ma. The age represents the formation age of the volcanic rock and indicates Xiaocaohu volcanic rocks is the part of the Carboniferous Tianshan igneous megaprovince. This new data has important information to study the Late Paleozoic tectonic structure of Beishan-China.



**Figure 1:** LA-ICP-MS U-Pb zircon of mylonitized dacite Concordia diagram.

## Thermal stability and gas generation of petroleum in the earth's subsurface based on kinetics modelling and field observations

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A typical marine origin crude oil from the Tarim Basin, NW China was pyrolysed in sealed gold tubes under constant pressure (50Mpa) and programmed heating (250-600°C) conditions, and chemical and carbon isotopic compositions of its generated gases were analyzed. A kinetics model for oil cracking was established and extrapolated to geological conditions. This model predicts that for a geological heating rate of 2°C/Ma a crude oil begins cracking to form gas at about 165°C (EasyRo=1.25%), attains 50% cracking at about 188°C (EasyRo=1.75%), is completely converted to gas about 215°C (EasyRo=2.5%), and is cracked to a dry gas ( $C_1/C_{1-5} > 0.95$ ) at around 263°C (EasyRo=3.9%). This oil cracking model is supported by field observations. A residual oil from the Cambrian carbonate reservoir in the eastern Tarim Basin is characterized by high density ( $1.02\text{g/cm}^3$ ) and a high content of polyaromatic compounds, indicating a strong thermal alteration. The fluid inclusion data from this reservoir and the geothermal evolution model for the area indicate the oil has experienced a maximum temperature of about 180-190°C. A further example is the Puguang gas reservoir in early Triassic rocks of the northeastern Sichuan Basin which has developed from a destroyed oil pool. The oil pool formed during the Jurassic based on kinetics modeling of the possible source rocks, and it is inferred from fluid inclusion and pyrobitumen reflectance data that it experienced a maximum temperature of around 250°C during the late Cretaceous. Thermal stress together with TSR (thermochemical sulphate reduction) resulted in the reservoired oil being completely altered to the  $\text{H}_2\text{S}$ -rich dry gas now forming the giant gas pool.

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## Lithium and boron isotope systematics during subduction and exhumation of UHP metamorphic rocks from Sulu, East China

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We use Li and B isotope systematics and bulk trace elements of ultrahigh-pressure metamorphic rocks from Sulu (East China) to investigate the role of fluids during subduction, material exchange between rocks representing the subducted slab and the mantle wedge, and exhumation. Our data reveal that there is significant Li and/or B isotope fractionation between different rock types that are in close contact during various metamorphic stages. Samples representing prograde dehydrated relics and hydrated areas have  $\delta^7\text{Li}$  of -6.9 and -0.4‰, respectively, which are different from that of their likely protolith (2-5‰), implying significant Li isotope fractionation during prograde dehydration. Garnet peridotite is enriched in B (4.5 ppm) and isotopically heavier ( $\delta^{11}\text{B} = +11.7\text{‰}$ ) than the close contacting eclogite which represents subducted rocks (0.9 ppm B;  $\delta^{11}\text{B} = 0.1\text{‰}$ ), indicating that the mantle rocks were metasomatized by fluids released from the subducted slab. Significant Li and B isotope fractionations of about 7‰ in close contact unaltered eclogite and retrograded amphibolite suggest an addition of retrograde fluids during exhumation. Li and B isotopic compositions combined with other geochemical tracers demonstrate that: (1) the UHP rocks have been severely dehydrated during subduction; besides Li- and B-loss and Li-B isotopic fractionation during progressive dehydration, in retrogression of the rocks there is an addition of fluids with isotopically heavier Li and B; (2) the slab released fluids may be transferred to form hydroxyl-bearing minerals-enriched (amphibole, phengite...) 'veins' rather than to produce large scale arc-magmatism as is usually observed in oceanic crust subduction zones; (3) on a limited scale mantle-derived rocks may be significantly metasomatized by fluids derived from the subducted slab; and (4) Li and B isotope fractionation may or may not behave coherently in the same system during slab subduction and subsequent exhumation of high-pressure and ultrahigh-pressure metamorphic rocks.

## Zircon SHRIMP U-Pb dating of volcanic rocks of the Jinniu Basin in the southeastern Hubei, MLYB, Eastern China

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The southeastern Hubei, MLYB is one of the most important Cu, Fe and Au mineralization districts in eastern China[1]. Late Mesozoic granitoids and volcanic rocks were dominantly genetically associated with lithospheric thinning induced to extension[2], the temporal relation of these magma has not been well constrained.

The Jinniu Basin showing an approximate S-N strike comprises the Majiashan Formation, the Lingxiang Formation and Dasi Formation upward. The volcanic rocks of the Majiashan and Lingxiang Formation are dominated by rhyolite and basalt, respectively. As the volumetrically dominant in the basin the Dasi volcanism can be divided into four subcycles, and are basalt and basaltic trachy-andesite and andesite and dacite and rhyolite[3]. The detailed analytical procedure were undertaken on SHRIMP II at the Beijing Ion Probe Center, CAGS.

The SHRIMP zircon U-Pb method of rhyolite and basalt from the Majiashan Formation and Lingxiang Formation was undertaken, respectively, and the weight average  $^{206}\text{Pb}/^{238}\text{U}$  ages of  $130 \pm 2\text{Ma}$  (n=13, MSWD=1.3) and  $128 \pm 1\text{Ma}$  (n=13, MSWD=1.2) were acquired, respectively, which are considered to represent the eruption age of the Majiashan Formation and the Lingxiang Formation, respectively. The timing of the Dasi Formation remains to be further studied. This result indicates that these volcanic rocks emplaced during the early Cretaceous period, which was latter than or simultaneously with these granitoids in southeastern Hubei, MLYB, Eastern China.

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## PbSL dating of garnet and staurolite: Constrains the age of peak metamorphism for Liaohe Group in the Eastern Block of the North China Craton

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The North China Craton is the largest and oldest known cratonic block in China. As a major lithostratigraphic unit of the Palaeoproterozoic Jiao-Liao-Ji Belt, the Liaohe Group occurs along a long, linear, North-east-trending belt in the eastern North China Craton. Many isotopic data for Liaohe Group are reported to constrain its volcanic components and some to its sedimentary components. However, the age of the peak metamorphism of Liaohe Group has not been well limited.

The isotope systematics of metamorphic minerals can be used to date parts of prograde thermal histories of metamorphic belts. Dating of a petrologically relevant mineral, such as garnet and staurolite, has the distinct advantage that time information ideally can be related directly to the pressure-temperature-deformation history recorded by the same mineral. In this paper we present the precise  $^{207}\text{Pb}/^{206}\text{Pb}$  stepwise-leaching (PbSL) isochron dating of garnet and staurolite from the metasedimentary rocks of the Liaohe Group.

The primitive Pb and radiogenic Pb are selectively extracted from garnet and staurolite by leach steps and determined by Multiple collector (MC-) ICP-MS. The data give  $^{207}\text{Pb}/^{206}\text{Pb}$  isochron ages of  $1883 \pm 25$  Ma ( $\pm 2\sigma$ , MSWD = 0.53) for garnet and  $1876 \pm 21$  Ma ( $\pm 2\sigma$ , MSWD = 1.5) for staurolite, respectively. They are identical to U-Pb age of metamorphic zircons from the Liaohe group ( $1955 \pm 130$  Ma) [1] and older than that of post-tectonic syenites (1843-1876 Ma) [2-3]. Therefore, the age of peak metamorphism of Liaohe Group is  $\sim 1880$  Ma.

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## The ages and geochemical characteristics of the Cretaceous basalts from Eastern Zhejiang, China

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The Early Cretaceous basalts occurring in eastern Zhejiang and Fujian provinces were stratigraphically divided into upper series (US) and lower series (LS), respectively. They have significant differences in the formation time and isotopic compositions.

Most zircons grains from the basalts in LS (BLS) show simple internal structure. They give  $t_{206\text{Pb}/238\text{U}} = 118 - 120$  Ma (SHRIMP date), and  $\text{Th}/\text{U} = 0.6 - 2.4$ , suggesting a magmatic origin. A few zircons show core-rim structure with the core of about 132 Ma and rim 115 Ma old. Zircons from the basalts in US (BUS) with simple structure give uniform ages of about 103 Ma, which is interpreted as the formation age. Relict zircons are identified in BUS, suggesting that the magma was contaminated by crustal rocks. BLS and BUS have similar REE pattern showing LREE enrichment but different trace elements and isotopes. The Cr and Ni concentrations of the both  $< 160$  and  $70$  ppm, and  $\text{Ni}/\text{MgO} < 15$ , lower than those of peridotite-derived melt. However, the BUS show higher Cr, Ni and lower Nb/Ta ratios than that of the BLS, and no HFSEs negative anomaly. BLS show  $I_{\text{Sr}}(\text{T}) = 0.7076 \sim 0.7096$ ,  $\epsilon_{\text{Nd}}(\text{T}) = -2 \sim -7$ , while BUS show  $I_{\text{Sr}}(\text{T}) = 0.7055 \sim 0.7062$ ,  $\epsilon_{\text{Nd}}(\text{T}) = +2 \sim -2$ . Because the Cenozoic basalts from eastern China have isotopic compositions similar to that of the MORB, we suggest that the geochemical characteristics of the lithospheric mantle in the area were transformed from enriched to depleted from 118 Ma to 103 Ma until the Cenozoic.

We conclude that the BLS were formed by the partial melting of the lithospheric mantle in 118 Ma and assimilated by small amount of the underplated 132 Ma old rock. After that, the extension was enhanced and the asthenosphere upwelled, the mixture of lithosphere- and asthenosphere-derived magma formed the BUS, which assimilated by small amount of crustal rock.

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## Impact of geotectonic on the formation of the Co-rich ferromanganese crusts

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Interest on Co-rich Ferromanganese Crusts (hereafter abbreviate the crust) is based on two main aspects: economically the Co, Pt and EER in the crusts has been considered to be potential metal resources and scientifically the compositions of the crusts acts as an indicator for the paleoceanography and paleochemistry of the environments in which the crusts form. The formation and distribution of the hydrogenetic crusts is controlled by a number of factors such as sea floor topography, water depth, structure of water column (oxygen minimum zone, carbonate compensation depth), type of substrate materials for the crusts, biological productivity, sedimentation, ocean current, especially Antarctic bottom water and upwelling. Our study of the crusts of 13 seamounts in the central Pacific (Line Islands Ridge, Midpacific Mountains) and the west Pacific Ocean (Magellan Seamounts, Marcus-Wake Ridge) show that the crusts are mainly distributed on seamounts, plateaux and aseismic ridges which are older than about 15 m.y.; the crusts have three growth periods and the crusts with 3 layer in the West Pacific Ocean more developed than that of the central Pacific; average thickness of the crusts above 2500m of water depth is increasing from 3.33cm of the east part of study areas to 6.67cm of the west part and the average content of cobalt in the crusts above 2500m of water depth is decreasing from 0.74% of the east part to 0.57% of the west part. Above mentioned phenomenon is caused by ocean plate and hot spots motion. The west Pacific and the central Pacific crust area is mainly distributed on linear seamount chains of hot spot origin, such as Magellan Seamounts, Marcus-Wake Ridge, Mid-pacific Mountains, Hawaiian Islands Chain and Line Islands Ridge. Most of linear volcanic chains in the Pacific are oriented west-northwesterly in general and formed sequentially above stationary hot spots during the past 42 m.y. as the Pacific plate rotated clockwise about a pole located near 69°N, 68°W (Clauge and Jarrard, 1973a). Another group of linear chains exhibit chiefly north-trending orientation and were formatted by the same mechanism between 80 and 42 m.y. ago as the Pacific plate rotated about a pole located near 17°N, 107°W (Clauge and Jarrard, 1973b). The early plate motion between 100 and 150m.y. into westerly direction. (Vallier *et al.*, 1983). The above mentioned plate and hot spot motion caused to form the seamounts, plateaux and ridge on the ocean floor and to open and close of sea passage and isthmus, which changed the pattern of ocean current, specially Antarctic bottom water with oxygen -rich and structure of water column such as oxygen minimum zone as well as biogeography and bioproductivity close related to the formation and distribution as well as composition of the crusts.

## Re-Os geochemistry of Barents Sea shales: Anisian-Ladinian stage boundary, faunal distributions, and hydrocarbon exploration

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Re-Os isotope geochemistry of C<sub>org</sub>-rich shales provides depositional ages and syndepositional seawater <sup>187</sup>Os/<sup>188</sup>Os ratios. Re-Os isochron ages calibrate biostratigraphic ages while seawater <sup>187</sup>Os/<sup>188</sup>Os ratios fingerprint hydrocarbon source rocks. Together, these data inform basin modeling, faunal distributions, and hydrocarbon exploration. Here we apply Re-Os geochronology to Anisian black shales from pristine outcrops in western Svalbard, and drill core from the submerged Svalis Dome, ~600 km SE in the Barents Sea.

Black shales of the Blanknuten Member, Botneheia Formation, western Spitsbergen Basin yield a Model 3 Re-Os age of 241 Ma and initial <sup>187</sup>Os/<sup>188</sup>Os (Os<sub>i</sub>) of 0.83. Black shale sample suites only 0.5 m apart in the Steinkobbe Formation from Svalis Dome IKU core 7323/07-U-09 (94-95 m) yield distinct ages, but indistinguishable Os<sub>i</sub>: 237 Ma (Os<sub>i</sub> = 0.69) above and 243 Ma (Os<sub>i</sub> = 0.65) below.

The sampled section in Svalbard underlies a distinctive *Frechites* (ammonite) layer, and is inferred to be middle to upper Anisian. The upper Steinkobbe section was sampled ~3 m above the late Anisian *Frechites laqueatus* zone and is thus assumed to be near the Anisian-Ladinian transition. Our results support correlation of the Botneheia and Steinkobbe Formations, and agree with the 237 ± 2 Ma age for the stage boundary based on magnetostratigraphy. The U-Pb zircon age for an ash bed at the GSSP in the Tethyan realm, however, is 3 to 4 m.y. older. This is problematic. If both radiometric ages are correct, then Baltic and Tethyan faunas may not be globally correlative. The high Os<sub>i</sub> for the Svalbard suite coincides with a sharp spike in seawater <sup>87</sup>Sr/<sup>86</sup>Sr in the Middle Triassic. The lower Os<sub>i</sub> in correlative units at Svalis Dome may reflect locally restricted seawater circulation. Large variations and sudden swings in seawater Os ratios show great potential for correlating hydrocarbons with their source rocks, provided paleogeographic constraints are taken into account.

## Geochemical characteristics and genesis of Bayin copper deposit in Xinjiang, China

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The Bayin medium-sized copper deposit is located in the eastern section of Southwest Tianshan, Xinjiang and the northern border of Youludusi mountain basin. It is strictly subject to the control of strata, structure and intrusive rocks, and there is occurrence of stratiform-like rocks in the basic volcanic rocks and sedimentary rocks of upper Silurian series.

The study investigates the ore mineral assemblages, zoning of wall rock alteration, REE composition and the isotope composition characteristics of sulfur, hydrogen and oxygen. The ore minerals are mainly chalcocite, chalcopyrite, bornite and so on, and they show granular structure and disseminated texture. The ore-forming temperature is between 130° to 140°, and the metallogenic hydrothermal mainly comes from magmatic water and metamorphic water, which belong to acid-rich fluid containing potassium, chlorine and carbon dioxide. The REE composition in ore-hosting volcanic rocks is similar to that in the unmineralizing volcanic rocks, and bears great difference with that in the vein ore bodies which came into being later. The sulfur isotope  $\delta^{34}\text{S}$  in ore minerals is at the range of -17.5‰ ~ +10.0‰, oxygen isotope is between -62.1‰ ~ -79.6‰, with  $\delta\text{O}^{18}$  being 12.3‰~13.5‰. The author holds that the formation of the deposit is related to the intermediate basic volcanic rocks formed in the immature environment of tensile rift in Upper Silurian. The metallogenic materials are chiefly derived from lower crust or the upper mantle. They have a same parent magma origin with volcanic rocks, and are characterized by a deep seated source feature.

The mineralization was formed by filling metasomatism of the Upper Silurian volcanic hydrothermal solution and superimposition of magmatic hydrothermal in early Hercynian period. It is a polygenetic compound deposit which is primarily featured by VMS-type Upper Silurian marine with the superimposition of granite magmatic hydrothermal in the late section of early Hercynian period.

Granted by the innovation team of ore-forming dynamics and prediction of concealed deposits, KMUST, Kunming, China (2008).

## Erosion rate measurements with cosmogenic <sup>36</sup>Cl in carbonate from Guizhou, China

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We have conducted a study of erosion rates in Guizhou karst area, southwestern China, to better understand geomorphological history of the area and to evaluate implications to the current environment. Surface lowering can be measured directly by micro erosion meters or calculated from the mass loss in rock tablets exposed to dissolution in different environments. Indirect approaches are based on the measurements of solute load leaving the catchment area, geomorphological investigations and methods of cosmogenic nuclides. Of these, cosmogenic nuclides are advantageous as they record the history of erosion and can bypass some of the extrapolation problems that other methods need to consider. Consequently we have collected carbonate samples from the study area and measured the cosmogenic <sup>36</sup>Cl concentrations.

In-situ cosmogenic <sup>36</sup>Cl is used as carbonate is essentially the only available sample form in the area and can safely be assumed to have reached equilibrium due to its half-life of 3.0e+5 years. The surface samples were collected from flat-lying ( $\pm 10^\circ$ ) outcrops chosen to avoid recent soil cover and to be as representative as possible of the surrounding landscape. After adjusting the <sup>36</sup>Cl production rates for sample latitude, altitude, thickness, horizon and target composition, erosion rates can be calculated. Variations and mechanisms of the local erosion rates are discussed and the results are compared with the existing observations obtained by other measurement techniques.

## Recycled lower continental crust: Re-Os isotopic evidence from peridotite xenoliths entrained by Mesozoic high-Mg diorites in the eastern North China Craton

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A suite of peridotite xenoliths including harzburgite, wehrlite, dunite, and orthopyroxenite entrained by the Early Cretaceous Laiwu high-Mg diorites in the eastern North China Craton (NCC) provide insight into the recycling of lower continental crust. Veined and zoned orthopyroxenes surrounding chromite, together sometimes with phlogopite, occur in spinel-harzburgite and chromite-bearing dunite. Residual olivine (Fo = 90-91) occurs in poikilitic clinopyroxene situated 1-2 mm from the wehrlite. The orthopyroxenes from orthopyroxenite veins in dunites have much higher REE abundances than primary orthopyroxenes from harzburgite, whereas poikilitic clinopyroxenes from wehrlite are characterized by strong enrichment in LREE and depletion in HREE. Different types of xenoliths all display 'U'-shaped REE patterns and have initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of 0.7058 ~ 0.7212 and  $\epsilon_{\text{Nd}}(t)$  values of + 0.18 ~ - 19.59. The initial  $^{87}\text{Os}/^{86}\text{Os}$  ratios of harzburgites, wehrlites, and dunites range from 0.10953 to 0.11023, from 0.12661 to 0.5765, and from 0.16221 to 0.73076, respectively, and show positive correlation with Cr# in spinels. Collectively, the harzburgites appear to be residues of slightly metasomatized ancient lithospheric mantle, which is supported by their Archean Re-depletion model ages of 2.6 ~ 2.68Ga, whereas the dunites and wehrlites are products of intensive interaction of the Archean lithosphere mantle with hydrous-bearing siliceous melt derived from partial melting of delaminated ancient lower continental crust.

## Zircon U-Pb dating and Geochemical study of volcanic rocks from Sunjiahe Formation of Xixiang Group in northern margin of Yangtze Plate

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The Sunjiahe Formation is distributed in Xixiang County along north margin of Yangtze Plate, Northwestern China, which is considered as part of Xixiang Group. The Sunjiahe Formation is a suit of low-metamorphosed volcano-sedimentary association, and is composed of basic, intermediate-basic and acid volcanic rocks with interbedding tuff, sediment-tuff, mudstone and siliceous rocks, the major rock types of volcanic rock are basalt, andesite, dacite and rhyolite. LA-ICPMS zircon U-Pb dating of rhyolite and basalt show us the ages of  $832.9 \pm 4.9\text{Ma}$  and  $845.0 \pm 17\text{Ma}$  respectively, implying rhyolites and basalts occurred at the same time in Neoproterozoic. Based on major, trace element, and Sr-Nd isotope data, the basalts can be classified into tholeiitic magma series and have the geochemical characteristics of crust-assimilated continental within-plate basaltic. In addition, basalts, andesites and dacites exhibit the same REE chondrite-normalized and trace element primitive mantle normalized patterns with overlapping one another, and samples plot along crystallized curve in Th-Cr diagram can be explained by crystallization from a common basic parental magma. On the other hand, the remarkable difference in REE and trace element normalized patterns of basalt, andesite, dacite and rhyolite suggests the different source. All the  $\epsilon_{\text{Nd}}(t)$  values of basalts, andesites and dacites greater than 0 and plotting in OIB region in  $\epsilon_{\text{Nd}}(t) - (^{87}\text{Sr}/^{86}\text{Sr})$  diagram indicate their source is similar to mantle source of OIB. Whereas, the rhyolites have the same  $\epsilon_{\text{Nd}}(t)$  values as basalts, suggesting rhyolite is generated by partial melting of juvenile basaltic crust. The age, tectonic setting and the development of continental rift intrusions in Yangtze Plate and in other areas in the world at the same time, showing the Sunjiahe formation is the product of continental riftism in Neoproterozoic, which is the precursor of the Neoproterozoic break-up of Rodinia supercontinent.

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## Zircon U-Pb ages of Devonian Molasse from the North Qilian Orogenic Belt, China: Provenance and tectonic affinity

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The NWW-SEE trending Qilian orogen formed during the late Caledonian collision between the North China Plate and the Qaidam Terrane, which divided into the North Qilian orogenic belt, the Middle Qilian Terrane and the South Qilian orogenic belt from north to south. The North Qilian orogenic belt is divided into four tectonic units from north to south: the Corridor back-arc basin, South Mountain of Corridor island-arc, subduction complex and obduction ocean-crust slice.

Devonian is the key period when the North Qilian orogenic belt uplifted quickly. A mass of terrestrial molasse was unevenly filled in the synorogenic basin on the northern margin of orogenic belt. The provenance of molasse is constrained by the U-Pb ages of detrital zircons, which shed light on the tectonic affinity of their source areas. The U-Pb age data for 158 detrital zircon grains in two sandstone samples from the Lower-Mid Devonian Laojunshan Fm. and Upper Devonian Shaliushui Fm. reveal the presence of 3.6-0.42Ga zircons, with the peaks in the Early-Paleozoic (451-438Ma), Neoproterozoic (968-941Ma) and Early-Proterozoic (2488-2447Ma). (1) Ages of the early Paleozoic and Neoproterozoic zircons are consistent with the time of island-arc and the high-grade metamorphic basement of the Middle Qilian Terrane, respectively. Ages of the early Proterozoic zircons indicate a source from the orogen or the North China Plate. (2) The occurrence of Neoproterozoic zircons indicate that the Middle Qilian Terrane had a strong affinity with the Yangtze Plate and might have belonged to the Gondwana supercontinent in the Neoproterozoic.

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## Geochemistry and geodynamics of Cenozoic magmatism in NE China

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Major, trace element and Sr-Nd-Pb isotopic composition are presented for Cenozoic basalts from the Mudanjiang-Mishan area, northeast China, with aims of investigating tempo-spatial variation of magmatism and geodynamics that governed magma generation. Tertiary alkali basalts have OIB-like trace element and positive  $\epsilon_{Nd}$  (1.1-5.4), suggesting a dominant asthenospheric origin. Overall, the isotopic composition of the Tertiary basalts from NE China can be accounted for in terms of mixing between three components (N-MORB, EMI and EMII). Temporally, the source of basalts have experienced three episodes of change: the mantle source of basalts erupted prior to the opening of the Japan Sea is characterized by an enriched lithospheric mantle (EMI); that of post-opening basalts is mainly of asthenosphere with both EMI and EMII components. In the spatial scheme, the basalts from continental margins show a prominent EMII signature, whereas those from the interior of the continent are characterized by a predominant EMI signature. Given this spatial distribution of mantle domains, EMII components may be related to subducting slab-derived melts, whereas EMI components are likely related to thinning of the old lithospheric root in eastern China[1]. It is proposed that the mantle flow associated with the lithospheric thinning underneath Eastern Asian continent is eastward, probably enhanced by the Indo-Asian collision and corner-suction of Pacific subduction [2, 3], whereas mantle flow triggered by subduction of Pacific plate is westward. Consequently, the mantle dynamics governing the genesis of the Cenozoic volcanism in NE China can be translated to the interaction between this two mantle regimes [4].

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## A new methodology for precise cadmium isotope analyses of seawater

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Previous studies have shown that biological uptake of Cd from seawater is associated with considerable isotope fractionation [1,2]. The most fractionated isotope compositions were determined for nutrient-depleted surface waters, which exhibit  $\epsilon^{114/110}\text{Cd}$  values of up to about +40 [1]. In contrast, seawater from the deep oceans was found to display a nearly constant Cd isotope composition of  $\epsilon^{114/110}\text{Cd} \approx +3$  [1], roughly similar to results obtained for the silicate Earth [3]. The origin and distribution of these distinct Cd isotope signatures will be further investigated as part of the GEOTRACES research initiative, to gain a better understanding of the biogeochemical cycling of Cd in the oceans, and to verify whether Cd isotopes can be employed to study past and present variations in marine nutrient utilization.

The low Cd concentrations (<10-20 pmol/L) that are commonly encountered in nutrient-depleted surface seawater pose a particular challenge for precise Cd isotope analyses. To cope with this problem, we have developed a new method for the determination of Cd isotope compositions that is suitable for the processing of seawater samples as large as 10 to 20 L. The procedure involves the use of a Cd double spike, co-precipitation of Cd from seawater using  $\text{Al}(\text{OH})_3$ , and subsequent Cd purification by anion-exchange chromatography. The Cd isotope analyses are then carried out by MC-ICPMS [4].

The performance of the technique was verified by analyzing multiple aliquots of a large seawater sample that was collected in the English Channel. The overall Cd yield of the procedure is consistently >85%, when the co-precipitation is carried out at optimized conditions (pH value,  $\text{Al}^{3+}$  concentration). Analyses that were carried with the new method were furthermore found to yield data, which are identical to results that were obtained with a previously published double spike methodology [4] but which is not suitable for the processing of large samples.

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## Molecular fossils extracted from an Ediacaran/Cambrian boundary section in the Three Gorge area, South China

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The Ediacaran/Cambrian boundary is one of the most important intervals for the evolution of life. It is essential to understand link between the global environmental changes and early animal evolution. Pristine drill core samples collected from the Three Gorge area, South China, was used for the systematic biomarker extraction in this study. A white dolostone without detectable TOC did not yield any biomarker molecules, indicating contaminations during drilling procedure and in laboratory extraction should be negligibly small. Acyclic isoprenoids (pristane and phytane) and n-alkanes were identified in almost samples. The distributions of n-alkanes often show bimodal distributions with two peaks at around  $n\text{C}_{17}$  and  $n\text{C}_{27}$ . This distribution pattern suggests the presence of two different source of hydrocarbon. Furthermore, in some samples, the long-chain n-alkanes with a peak around  $n\text{C}_{27}$  predominate over short-chain ones having a maximum at  $n\text{C}_{27}$ . The predominance of the long-chain n-alkane occurs particularly across the Pc/C and Nemakit-Daldynian/Tomotion boundaries, where major biological diversifications have been known to occur. The long-chain hydrocarbons could have been originated from some specific eukaryotic algae, and thus their predominant occurrences biostratigraphic boundaries may suggest blooming of single or a few species. The decline of biodiversity is likely to have occurred due to severe environmental stress like oceanic anoxia (Pc/C) and global cooling (Nd/T) [1]. The observed  $n\text{C}_{16-18}/n\text{C}_{26-28}$  anomalies may witness the biological turnover.

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