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Geochemistry and SHRIMP geochronology of alkaline rocks of the Zijinshan massif in the eastern Ordos basin, China

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Abstract

Characteristics of geology, petrology, and geochemistry of the Zijinshan massif were studied in the eastern part of the Ordos basin. Geochemical analysis shows that the massif is characterized by high alkali, relatively high Fe, and low Mg and Ca contents. The rocks are undersaturated in SiO_2, rich in REE (with no Eu anomaly) and belong to the alkaline-peralkaline series. The geologic history of the Zijinshan massif consists of several stages of magmatism. The obtained isotope-geochronological (U-Pb SHRIMP) data show that the magmatic activity climaxed in the interval 150–110 Ma, while the age of 16 zircon grains fitted a narrower interval, 132–125 Ma, i.e., the Early Cretaceous. The younger age corresponds to the middle and late stages of the evolution of the Ordos basin and agrees with a large Early Cretaceous tectonothermal event in North China. This event led to the large-scale uplift of the eastern flank of the Ordos basin, rise of the Lüliang asthenosphere, and to the formation of a large west-sloping monocline. The U-Pb SHRIMP studies have also revealed magmatic zircons of Carboniferous–Permian age, which evidences the multistage character of the thermal process.

Keywords: Ordos basin; magmatic activity; tectonic thermal event; Early Cretaceous; Zijinshan; SHRIMP chronology

Introduction

In the study of the dynamics of basin formation the greatest challenges are the thermal process and thermal structure of the basin (He and Li, 1995; Liu, 2005; Ma et al., 2003). Chinese authors believe that thermal structures of basins can be classified in detail on the basis of their present-day structure, geomorphological type, age of deposits, and depth of thermal (magmatic) effect. According to the depth of thermal (magmatic) action, five types of tectonic structures have recently been recognized (Yang et al., 2005): (1) faulting zones with related ancient geothermal anomalies; (2) zones of high hydrothermal-volcanic activity (with manifestations of subsurface effusive magmatism, hydrothermal activity and hypabyssal porphyry intrusions); (3) thermal dome; (4) structure with medium-depth intrusions (including intracrustal thermal plume anomalies); (5) mantle-derived thermal plumes.

The Ordos basin is not only among the basins where first oil fields were found but also it is the second largest oil basin in the world. It lies in the west of the North China craton (Fig. 1, inset right above) in the zone of junction of two tectonic regions (eastern and western) which underwent multiple expansion and compression. It is a complicate intracratonic basin (Ingersoll and Busby, 1995) resulting from multiple superposition of various structures upon the primary Ordos basin. Seismic and magmatic activities were earlier studied on the southeastern margin of the Ordos basin (Fen–Wei rift). The Shanxi flexural foldbelt is situated in the eastern part of the basin (Fig. 1, inset left below). It is a giant monoclinal structure dipping from east to west (Yang, 2002), complicated by a series of open flat meridional subfolds, by the Wubu sublatitudinal fault (F_1), and by the large Lishi submeridional fault (F_2). The folds and faults are mostly semiconcealed. Along with the problems of tectonics, mineralization, and oil accumulation in this basin, worthy of discussion is a possible thermal effect of a deep-seated magma source in the eastern part of the basin and on its periphery.

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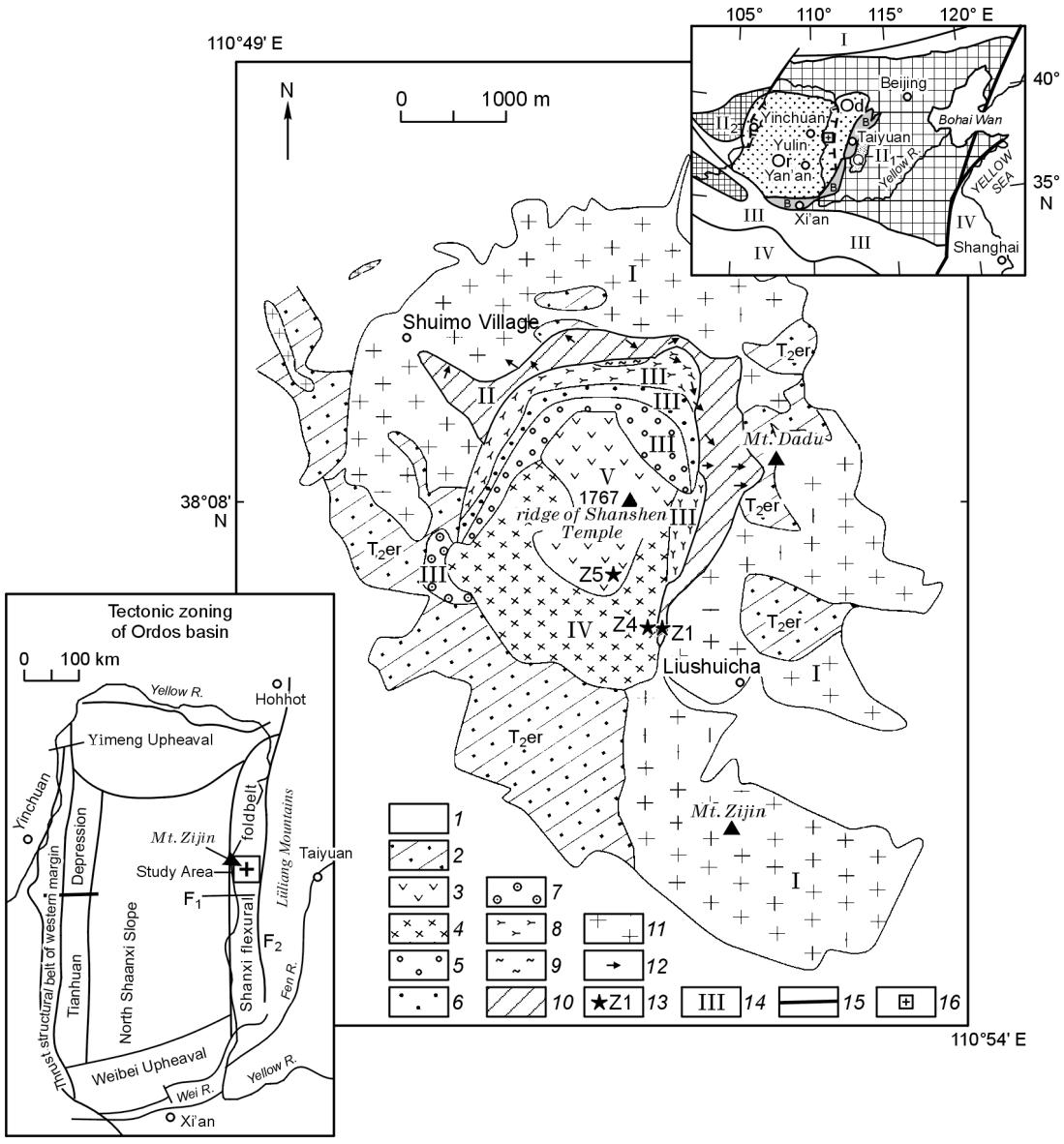

Fig. 1. Schematic geological structure of the Zijinshan massif (modified after: Wu, 1966). *1*, Quaternary deposits; *2*, sandstones and shales of the Ermaying Group of Middle Triassic age (T_2er); *3*, trachyte porphyries and trachyte volcanic breccias; *4*, pseudoleucite phonolites and phonolite volcanic breccias; *5*, melanite-aegirine-augite nepheline syenite; *6*, aegirine-augite nepheline syenite; *7*, biotite-melanite nepheline syenite; *8*, malignite; *9*, nepheline titanaugite; *10*, aegirine-augite syenite; *11*, monzonite; *12*, flow directions; *13*, sampling localities and sample numbers; *14*, zone numbers; *15*, faults (F_1 is the Wubu fault and F_2 is the Lishi fault); *16*, area under study. The upper right inset shows the location of the study area on the structural-geological scheme of Northeastern China: I, Great Hingayn–Mongolian orogenic belt; II_1, North China craton, II_2, Alashan block; III, orogenic belt of the Qinling–Dabieshan; IV, Yangtze craton; Or, Ordos basin; Od, large Ordos basin; Q, Qinshui basin; B, Fen–Wei rift.

Analysis of the isotope-geochronological data on intrusive bodies of the eastern part of the basin obtained earlier by the Rb-Sr method (Huang, 1991; Luo et al., 1999; Tang et al., 1992; Zhou et al., 1996) and K-Ar method (Shanxi..., 1989) and recent zircon U-Pb age of 127 Ma (Ying et al., 2007) allows the estimated ages of magmatism to be divided into five intervals: 94–91 Ma (K_2), 132–125 Ma (K_1), 154–141 Ma (J_3), 293–287 Ma (P_1), and 343 Ma (C_1). The earlier data are widely dispersed and rather uncertain.

Based on the field works in the Zijinshan alkaline massif, analysis of the samples, their petrogeochemical characteristics, and U-Pb SHRIMP ages, this paper describes stages, sources, and evolution of magmatism. The available data suggest a medium-depth source of the magma intruded on the eastern flank of the Ordos basin. According to the U-Pb SHRIMP dating, the main stage of magmatism dates from the Early Cretaceous. Hence, a succession of magmatic events has been established, which is very important for reconstructing tectonothermal events in this region.

Geological characteristics of the Zijinshan alkaline massif

The Zijinshan alkaline massif localized in the northwestern Lin County of the Shanxi Province is composed of Mt. Zijin,