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The association of mafic–ultramafic intrusions and A-type magmatism in the Tian Shan and Altay orogens, NW China: Implications for geodynamic evolution and potential for the discovery of new ore deposits

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Abstract

The NW China region is characterised by tectonic and lithostratigraphic domains, such as the Tian Shan and Altay orogens, the Tarim, Junggar and Turpan Basins. The Tian Shan and Altay orogens are part of the Central Asian Orogenic Belt. The NW China region was affected by a series of thermal events that occurred between the Silurian and the Triassic, which resulted in the emplacement of numerous granitic plutons and mafic–ultramafic intrusions. A number of these granitic plutons are of A-type affiliation, which on the basis of the positive εNd values are likely to have been derived from mantle sources. In addition, at least two large igneous provinces (LIPs) can be recognised in NW China, namely the 345–325 Ma Tian Shan LIP and the ca. 270–280 Ma Tarim LIP. Age and field data suggest a spatial and temporal relationship between the mafic–ultramafic intrusions and A-type granites within the LIPs. In this paper we discuss mafic–ultramafic intrusions that host magmatic Ni–Cu sulphide deposits (Kalatongke in the Altay, Huangshan and Poyi–Poshi) in the eastern Tian Shan. These intrusions are typically zoned, characterised by an envelope of early gabbroic rocks that enclose later ultramafic units. These zoned mafic–ultramafic intrusions have some features that are comparable with Alaskan-type complexes. Taking into consideration the spatial–temporal relationship of the mafic, mafic–ultramafic rocks and A-type granites, we suggest that these magmatic events occurred during an extensional regime, possibly related to a mantle superplume event that affected much of central Asia during the Permian, of which the Siberian Traps and the Emeishan continental flood basalts of SW China are part. If the A-type felsic magmatism took place during a superplume event, we also suggest that these rocks may be conducive to host iron–oxide–copper–gold (IOCG) style mineralisation. We conclude with a model that attempts to explain the relationship between the zoned mafic–ultramafic intrusions and mantle plume activity in NW China during the Permian.

Keywords: Tian Shan and Altay orogens; Tarim; Junggar; Mafic–ultramafic intrusions; Large igneous provinces; Mantle plume

1. Introduction

The NW China region encompasses terranes and tectonic units that are part of the great Central Asian Orogenic Belt (CAOB; Jahn, 2004) or Altaid orogenic collage (Sengör et al., 1993), or Central Asian Orogenic Supercollage (Yakubchuk et al., 2005). More recently, the CAOB was described in some detail by Windley et al. (2007). The CAOB extends from the Uralides in the west to the Pacific Ocean margin of eastern Asia and is bounded to the north by the Siberian Craton and to the south by the Tarim–North China cratonic blocks (Fig. 1). The CAOB is a complex collage of fragments of ancient microcontinents and arc terranes, fragments of oceanic volcanic islands (e.g. seamounts), perhaps also volcanic plateaux (e.g. Junggar block, discussed below), oceanic crust (ophiolites), and successions formed at passive continental

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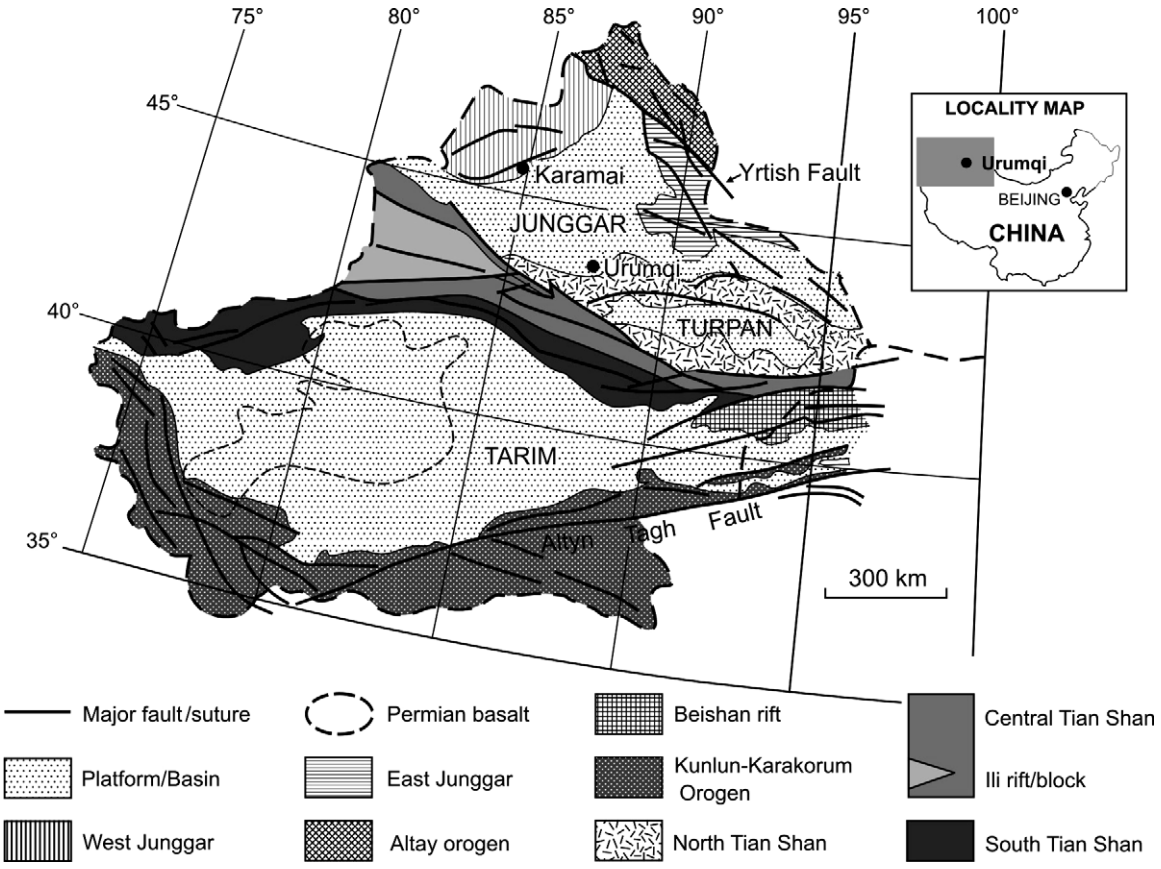

Fig. 1. Simplified geological map of northwestern China, showing main tectonic units. After Pirajno et al. (1997) and Bureau of Geology and Mineral Resources of Xingjiang Uygur Autonomous Province (1993). Extent of flood basalts on the Tarim platform is simplified and taken from Chen et al. (2006).

margins. The amalgamation of these terranes occurred at various times in the Palaeozoic and Mesozoic and was accompanied by episodes of magmatism, ranging in age from Ordovician (ca. 450 Ma) to Triassic–Cretaceous (ca. 220–120 Ma) that resulted in the emplacement of large volumes of granitoid intrusions (Jahn, 2004) and mafic volcanic rocks (Wang et al., 2007; Zhu et al., 2005), accompanied by lesser volumes of mafic–ultramafic material. A-type granitic and peralkaline intrusions in the CAOB are common and are associated with post-collisional tectonism. Elsewhere, in NE China and Mongolia, A-type granites are associated with extensive Mesozoic and Tertiary volcanism (Jahn, 2004). Nd–Sr isotope studies indicate that these A-type and peralkaline granites are juvenile and of mantle origin (Jahn, 2004).

In NW China the Altay Orogen, Junggar Basin and the Tian Shan orogenic belt, as mentioned above, are characterised by accreted terranes and that include island arcs, oceanic crust and continental fragments. These terranes were later affected by rifting processes and post-collision intraplate rift magmatism with granitic, mafic–ultramafic intrusions and continental flood basalts, between the Carboniferous–Permian and the Late Cretaceous (Allen et al., 1992; Xia et al., 2003, 2004). There are at least four major Phanerozoic intraplate magmatic events that have affected the region, in order of decreasing ages: (1) ca. 410–390 Ma; (2) ca. 330–310 Ma, (3) ca. 300–270 Ma; (4) and ca. 250 Ma, as further elaborated in Section 5.

In this paper, the geology and origin of a number of mineralised mafic–ultramafic systems are discussed. These mafic–ultramafic systems are part of a series of intrusive bodies, commonly found along faults or sutures and that have been generally labelled ophiolites (that is originating from and representing fragments of oceanic crust, e.g. Hsü, 2003; Zhou et al., 2004; Sengör and Natal'in, 2004), that are present in the Altay and Tian Shan orogens. Typically, these intrusions are funnel-shaped and concentrically zoned with lenses of ultramafic rocks enclosed in an envelope of gabbroic composition. We draw information from published literature as well as our own field, unpublished and published data to show that most of these systems are not ophiolites *sensu stricto*, but formed as intrusive complexes that were emplaced as a result of within-plate magmatic activity. We examine the possibility, in the light of mantle dynamics, that these funnel-shaped and zoned mafic–ultramafic intrusions are a variant of Alaskan-type complexes and suggest a geodynamic model invoking the upward movement of a series of "plumelets" rising from the head of a mantle plume(s) that impinged onto the lithosphere in Permian–Triassic times, following the collision or amalgamation of the terranes that constitute the Altay and Tian Shan orogens.