فرورانش دوسویه نامتقارن؛
نظریه جدید در مورد محیط تکتونوماگمایی و متالوژنی بلوک لوت، شرق ایران

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چکیده:

محیط تکتونوماگماتیسم و متالوژنی بلوک لوت در حال حاضر مورد بحث است و نظریات بسیاری مطرح شده‌اند. یکی از موارد مورد بحث اهمیت فرایندهای فرورانش برای توضیح ویژگی‌های زمین‌شناسی بلوک لوت است. علیرغم اینکه برخی مسئله فرورانش را مردود دانسته‌اند اما اکثر محققین معتقدند که فرورانش پوسته اقیانوسی نقش مهمی در تحولات تکتونیکی این منطقه داشته است. تاکنون دو مدل ژئودینامیکی مربوط به فرورانش ارائه شده‌اند: برخی فرورانش را به زیر بلوک افغان در نظر گرفته‌اند در حالیکه عده‌ای معتقدند که پوسته اقیانوسی به زیر بلوک لوت کشیده شده است. داده‌های جدید عناصر کمیاب و ژئوشیمی ایزوتوپی از توده‌های نفوذی الیگوسن مناطق دهسلم و چاهشلغمی وجود یک محیط فرورانش را در زیر بلوک لوت اثبات کرده است. از طرف دیگر شواهد ساختاری نشان دهنده فرورانش به زیر بلوک افغان نیز وجود دارند. بمنظور توضیح مهمترین ویژگی‌های تکتونوماگماتیسم و متالوژنی بلوک لوت نظریه جدید در این مقاله ارائه می‌شود که شامل فرورانش دوسویه نامتقارن به زیر هر دو بلوک لوت و افغان با سرعتهای متفاوت می‌باشد.

Two sided asymmetric subduction: new hypothesis for the tectonomagmatic and metallogenic setting of the Lut Block, Eastern Iran

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Abstract

The tectonomagmatic and metallogenic setting of the Lut Block is still a matter of debate and several hypotheses have been put forward. One of the issues of that discussion is the importance of subduction processes to explain the geological features of the Lut Block. Despite some authors deny the influence of the operation of Benioff planes, most of the recent works consider that subduction of oceanic lithosphere had a major role in the tectonic evolution of this area. Until now, two types of geodynamic models considering subduction have been presented: some authors propose that it occurred beneath the Afghan block, whilst others consider that oceanic lithosphere was dragged under the Lut block. New trace element and isotope geochemical data, obtained in the Oligocene intrusives from Dehsalm and Chah-shaljami areas, indicate that a subduction zone existed below the Lut block. On the other hand, structural evidence shows that subduction occurred beneath the Afghan block. In order to explain the most important tectonomagmatic and metallogenic characteristic of the Lut Block, a new hypothesis is presented in this work, considering a two sided asymmetric subduction beneath both Afghan and Lut blocks, with different rates of consumption of oceanic lithosphere.

Introduction

The Lut Block has been considered one of the nine structural zones of Iran since the work of Stöcklin (1968).This block is bounded to the east by the Nehbandan and associated faults, to the north by the Doruneh and related faults (Sabzevar Zone), and to the west by the Nayband Fault. The South Jazmourian fault, in the south of Sahand-Bazman magmatic arc, probably marks the southern limit of the block (Berberian, 1981). The present eastern border of the Lut block would have belonged to the active margin of the subducted Neotethys Ocean (Bagheri and Stampfli 2008). This ocean was closed in eastern Iran, between the Helmand and Lut plates, in Oligocene–Middle Miocene (Sengör and Natalin, 1996). Some authors denied the influence of a subduction zone and attributed the mineralization in the Lut Block to an extensional geotectonic zone (Samani et al., 1992). However, Saccani et al. (2010) studied the ophiolitic complex of Eastern Iran, between the Lut and the Afghan continental blocks, and considered that the subduction of oceanic lithosphere had a major role and that it should have taken place beneath the Afghan block. On the other hand, Eftekharnejad (1981) proposed that magmatism in the northern Lut area resulted from subduction beneath the Lut Block. Additionally, Berberian (1983) has shown that igneous rocks of this block have calcalkaline signatures. The accretionary prism-forearc basin polarity, the structural vergence and younging of the accretionary prism to the southwest are consistent with a northeast-dipping subduction (Tirrul et al., 1983). Recently, asymmetric subduction models have been discussed for situations similar to that of the Lut Block. This type of hypothesis will be discussed in the present work, taking into account that subduction related magmatism occurs in both Lut and Afghan blocks but also that the structural evidence alone would point to a single subduction under the Afghan Block. Another purpose of this work is to present new geochemical (both elemental and isotopic) data from Dehsalm and Chah-shaljami granitoids, aiming at establishing tighter constraints to the petrogenetic processes and the geodynamic evolution of the Lut Block.

Analytical techniques

Twenty five samples were analysed for major element contents by X-ray fluorescence (XRF) spectrometry at Ferdowsi University, Mashhad, Iran. Twenty of these samples were selected for trace element analysis by ICP-MS, in Acme laboratories, Vancouver, Canada. Sr and Nd isotopic compositions were determined, in 14 whole rock samples of the Dehsalm and Chah-Shaljami granitoids, by TIMS at the Laboratório de Geologia Isotópica da Universidade de Aveiro, Portugal.

Geological setting

Chah-shaljami and Dehsalm porphyritic granitoids belong to the Lut Block volcanic-plutonic belt of eastern Iran (fig1). The Chah-shaljami complex is located 190 km to the south of Birjand, in the Lut Block volcanic-plutonic belt. It is composed of sub-volcanic rocks that define a compositional range from quartz diorite to biotite granite, through quartz monzodiorite, quartz monzonite and granodiorite. Biotite and hornblende are typically the most abundant mafic phases. This complex intrudes volcanic rocks, mainly andesites and pyroclastics.

The Dehsalm intrusive complex is located about 55km west of Nehbandan; South Khorasan, Iran and intruded into Eocene volcanics, sandstone and siltstone. On the basis of petrographic studies, the intrusive rocks cropping out at Dehsalm are gabbroic diorites, diorites, monzodiorites and quartz monzonites. The main mafic minerals are usually hornblende and biotite, but clinopyroxene and, sometimes, orthopyroxene may be observed in the least evolved rocks.

Geochemistry

The Dehsalm and Chah-shaljami intrusives are classified as volcanic arc granites according to the criteria proposed by Pearce et al (1984). Primitive mantle normalized trace element spider diagrams(Sun and McDonough, 1989) display strong enrichment in LILE, such as Rb, Ba and Cs,

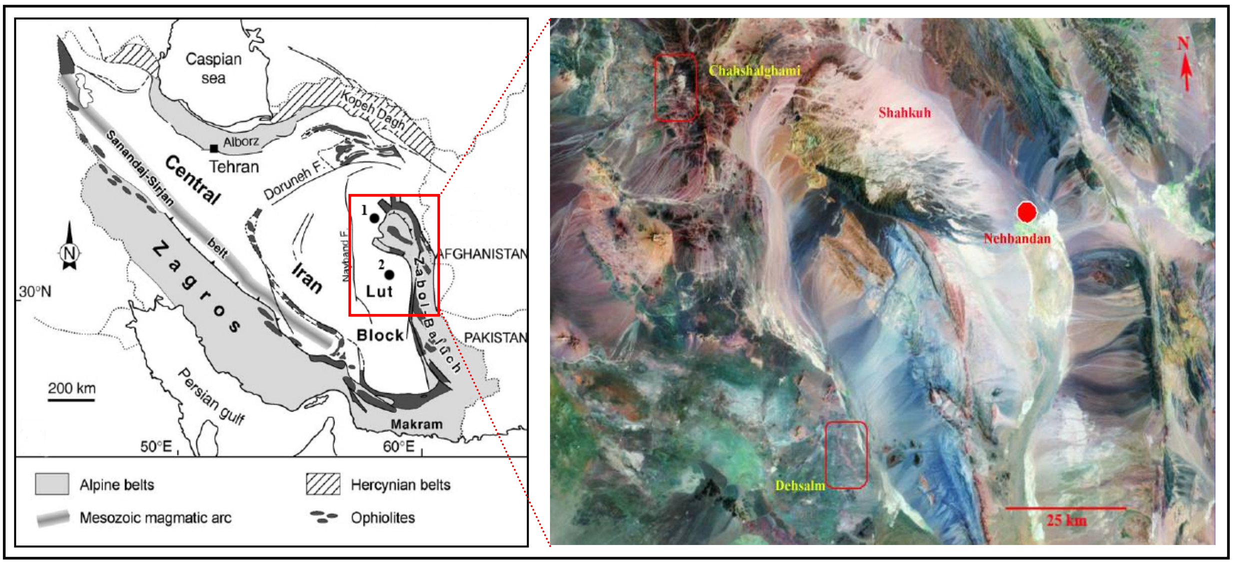

Fig1: Geological sketch map of Iran after Berberian and King (1981) and the location of Dehsalm and Chah-shaljami intrusives on satellite image.

and depletion in some high field strength elements (HFSE), e.g. Nb, P and Y (Fig. 2 a-b). REE patterns in chondrite normalized plots display high degrees of REE fractionation, with very strong LREE enrichment, whilst Eu has not anomalies or shows only very slight negative anomalies (Fig. 2 c-d). LILE enrichment and depletion in some HFSE are characteristics typical of the magmatism in subduction related belts (Wilson, 1989), such as the calc alkaline volcanic arcs. Their high Sr and low Nb, Ta and Ti contents are thought to be due to the absence of plagioclase and presence of Fe–Ti oxides in the residue in the source area of the parental magmas (Martin, 1999). Furthermore, low molar Al_2O_3/Na_2O+K_2O+CaO ratios (<1.1); and low Rb/Sr ratios for Dehsalm and Chah-shaljami intrusives indicate that these rocks are I-type granitoids. Sr/Y and La/Yb are respectively 31.6-72.2 and 21.5-33.5 in the Dehsalm rocks, whilst the Chahshalghami intrusives display 19.7-67 and 21.4-33.7 for the same ratios, showing that both complexes have geochemical features similar to those of adakites, which become clear by plotting the data on the Sr/Y–Y and La/Yb–Yb diagrams (Kepezhinskas et al. 1997; Castillo et al 1999) (Fig. 3 a-b). However, the Dehsalm and Chah-shaljami can not be considered as typical adakites, mainly because they have high K_2O/Na_2O ratios, which reveals that the studied rocks also have a shoshonitic affinity.
High Sr/Y and La/Yb ratios and low HFSE (specially, HREE) may result from melting of garnet amphibolite or eclogite facies rocks, which are expected to occur at the base of thickened (>40 km) continental crust or in subducted oceanic crust. On the other hand, garnet is also a stable phase in the subcontinental mantle lithosphere as well as in the asthenosphere (Poli and Schmidt, 2002; Grove et al., 2006). The low contents of Y and Yb and the high Sr/Y and La/Yb ratios can be attributed to the retention of Y and HREE in residual garnet, or to fractionation of garnet and hornblende. High Sr content may result from the absence of significant plagioclase fractionation. Hornblende and/or Fe–Ti oxides (rutile, ilmenite) are common residual minerals, thus, being able to account for Ti–Nb–Ta negative anomalies in calc-alkaline rocks.
Sr and Nd isotope ratios of the Dehsalm and Chah-shaljami intrusives define a tight cluster that plots slightly to the right of the of the mantle array, suggesting that both suites derive from very

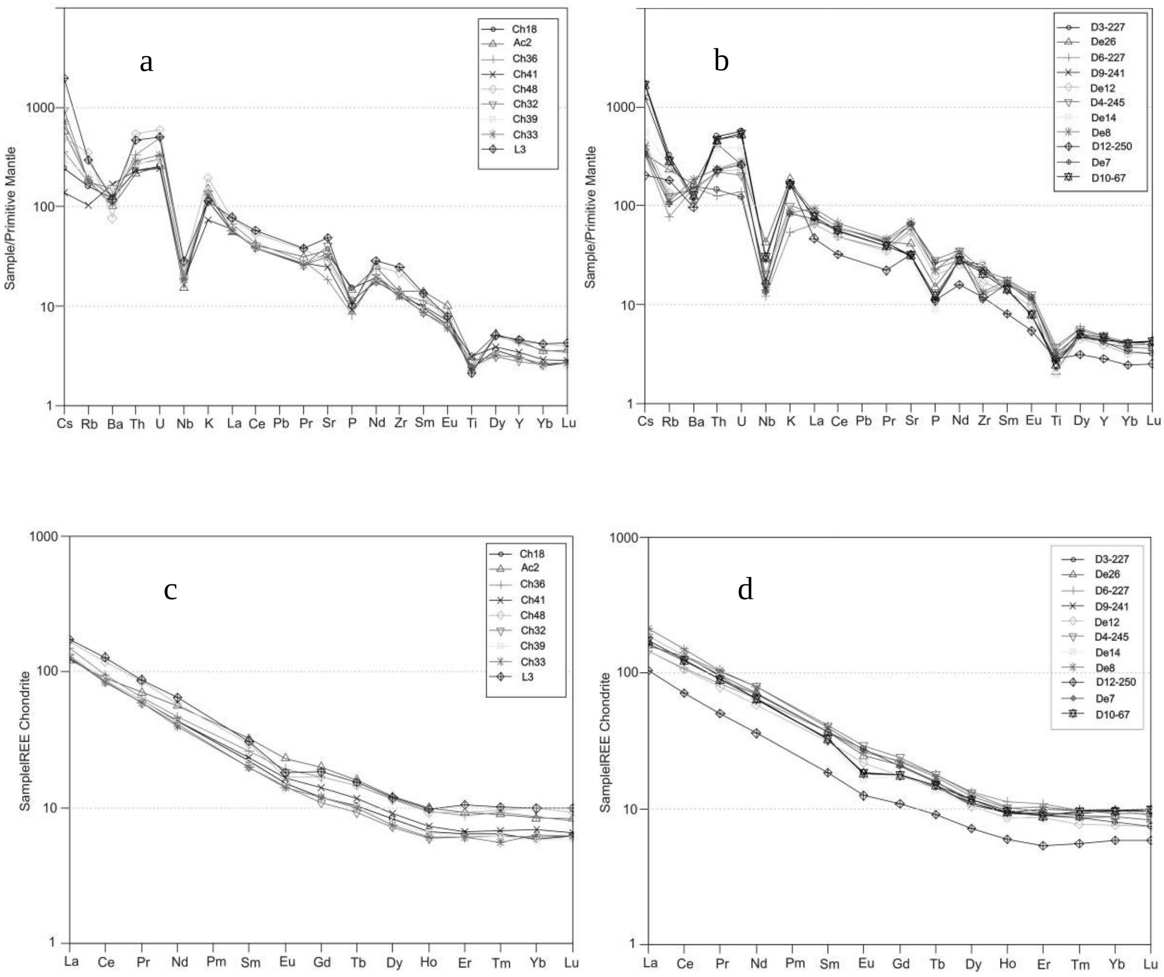

Fig2; a, b: Primitive mantle normalized trace element spider diagram (Sun and McDonough, 1989) and C, d: REE chondrite-normalized diagram (Boynton, 1984) for Dehsalm and Chahshalghami intrusives.

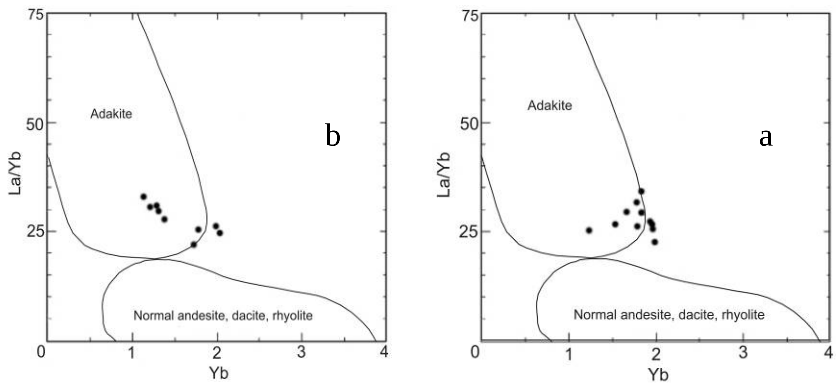

Fig3: Yb vs. La/Yb diagram (after Defant and Drummond, 1990) used to differentiate adakitic magmas from typical calc-alkaline magmas for a: Dehsalm and b: Chah-shaljami intrusives

similar mantle derived parental melts and that the compositional ranges found were produced mainly by magmatic differentiation. Furthermore, the position of the cluster in εNd vs. εSr diagram is typical of igneous rocks from convergent plate margins. On the other hand, the luster plots outside the field of the Cenozoic subducted oceanic crust-derived adakites, which makes unlikely that the parental magmas were slab melts. The two samples that do not lie within that cluster reveal, in one case, severe hydrothermal alteration and, in the other case, some sort of contamination by continental crust material.

Tectonomagmatic implications

West directed subduction zones, like Marianas and Tonga, show a number of common characteristics, such as low topography, a generally steep slab, an accretionary prism mostly composed of shallow rocks of the lower plate and a conjugate backarc basin. In contrast, east directed subduction zones, like Andes, or north-east directed, like Himalayas, exhibit opposite signatures such as high structural elevation, generally no backarc basin, deeply rooted thrust planes affecting the whole crust and the lithospheric mantle, wide outcrops of metamorphic rocks, and dominantly low angle dip of the slab. The E or NE directed slabs have also slower sinking velocity than the opposite W-directed subduction zones (Fig. 4). West-verging subduction would be completely consumed before E or NE-verging subduction and consequently lead to the formation of structures that show evidences of one sided subduction as reported between the Lut and Afghan blocks. For example the accretionary prism-forearc basin polarity, the structural vergence and younging of the accretionary prism to the southwest are consistent with a NE dipping subduction beneath Afghan block (Tirrul et al., 1983). Tatsumi and Eggins (1995) have shown a correlation between convergence rate and volumes of magmatism along subduction zones. The larger volumes of subduction predicted along W-directed slabs should favour the formation of greater amounts of arc-related magmas, as reported within the Lut block, where voluminous Tertiary igneous rocks occur. Therefore, structural evidence for E or NE-verging subduction does not preclude W-directed subduction under the Lut block and a model with two sided subduction has the advantage of also accounting for the very important Tertiary calcalkaline magmatism and associated mineralization within this block.

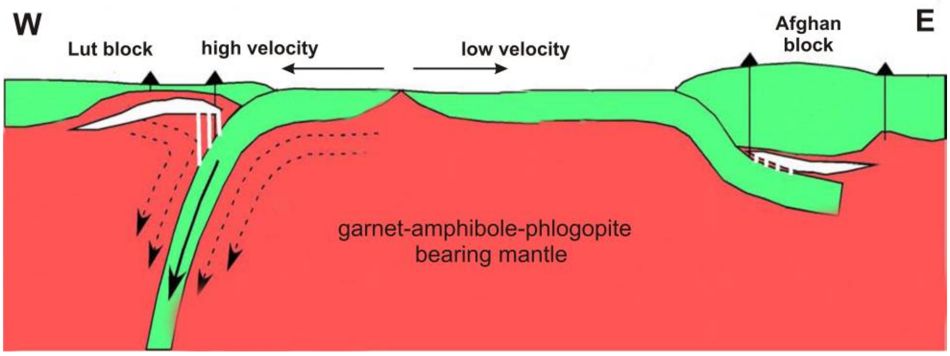

Fig4: Simplified global two sided asymmetric subduction. This model is presented as a new hypothesis for the tectonomagmatic and metallogenic setting of the Lut block.

Recent exploration and petrologic studies on the Lut block volcanic-plutonic belt show capabilities and suitable targets for Cu-Au-Mo porphyry epithermal mineralization (Arjmandzadeh et al., 2010; Karimpour, 2009) that are related to a subduction zone.

Conclusions

The Dehsalm and Chah-shaljami porphyritic granitoids in the Lut Block represent a continental arc setting associated with the magmatism above a subduction zone. The intrusives are calc-alkaline, I-type and belong to the magnetite series, showing potential for Mo-Cu-Au economic mineralizations as detected by geochemical exploration. The adakitic affinity of Dehsalm and Chah-shaljami intrusives is not related to pure slab melts, but can be attributed to the presence of garnet and low-Mg amphibole in the mantle. The features of the studied rocks provide new evidence for subduction beneath the Lut block during the Tertiary. Two sided asymmetric subduction is a new geodynamic model for this area, and it explains the tectonic, magmatic and metallogenic characteristics of the Lut block.

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