The age of metasedimentary rocks and their regional metamorphism in the Soursat Complex, NW IRAN: U–Pb dating of zircon and monazite, using LA–ICP-MS

Jamshidi Badr Mahboobeh *,[1], Collins[2] Alan S, Masoudi Fariborz [1, 3]

Corresponding author:
1. Tarbiat Moallem University, 49, Mofateh Ave, Tehran. Iran *Payame Noor University Iran *Karaj Islamic Azad University Iran.

2. Tectonics Resource and Exploration (Trax), School of Earth and Environmental Sciences, University of Adelaide, Australia

3. Shahid Beheshti University
E-mail address: m_jamshidi@tmu.ac.ir.

Abstract
The Soursat Metamorphic Complex (SMC) in northwestern Iran is one of the main metamorphic terranes *in northern Sanandaj-Sirjan metamorphic belt. The complex composed mainly of metamorphic rocks associated with granitic intrusions. Metamorphic rocks vary from greenschist to amphibolite facies and consist of mica-schist, garnet-schist, staurolite-schist, andalusite-schist, cordierite- schist, marble, gneiss and granite-gneiss. SMC is in tectonic contact with Precambrian to Paleozoic sedimentary rocks (Kahar, Bayandor, Soltaniyeh, Barut, Zaigon, Lalun and Mila formations) which make it difficult to date it based on stratigraphy. In this study U/Pb dating of zircons and Monazites used in order to find the ages of deposition and metamorphism of metasediments in SMC. U/Pb dating of zircons from a staurolite-schist in the complex by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) yielded a maximum depositional age of 605±43 ($^{238}U/^{206}Pb$ age). Monazites were also dated from a garnet-schist using the same technique and yielded a $^{238}U/^{206}Pb$ age of 61±8 which is interpreted as dating the peak of regional metamorphism. Based on these ages, metasedimentary protoliths of the Soursat Complex are interpreted to be deposited at the same time as the surrounding essentially unmetamorphosed Precambrian-Cambrian sedimentary rocks and regional metamorphism occurred later and could be related to the Paleocene orogenesis during the collision of Arabian plate with Iranian block and closure of Neotethys.*

Keywords: *LA-ICP-MS; Zircon; Monazite; NW Iran; Sanandaj-Sirjan; Soursat Complex.*

Introduction
Precambrian terranes are exposed in many places in Iran. In the Saghand Region, Central Iran, Soursat (Soursat Metamorphic Complex), Zanjan (Takab Complex), Gorgan, Golpayegan and etc, basement complexes occur as the oldest lithostratigraphic element (e.g. Haghipour, 1974 & 1981; Nadimi, 2007; Hassanzadeh et al. 2008; Horton et al., 2008; Saki, 2009).

The term “basement complex” is used for the set of rocks underlying the Pan African unconformity and comprising mostly metamorphic or igneous rocks (with the age of the bottom of the related rock cover being variable, ranging in most cases from 570 to 500 Ma).

Soursat Metamorphic Complex (SMC) is in tectonic contact with Precambrian to Paleozoic sedimentary rocks which make it difficult to date it based on stratigraphy.

An early attempt on dating of the complex was focused on its intrusions (Pichagchi pluton) and K-Ar techniques yielded an age of 74.20 Ma (Kholghi khasraghi, 2004). This age has directly influenced palaeogeographic and plate tectonic reconstructions (Kholghi khasraghi, 1994). Recently, The U/Pb Zircon dating of intruded granitoid rocks in SCM (Jamshidi Badr et al. 2009a) presented two set of intrusions with Ediacaran-Cambrian and Palaeocene ages. Old ages from granitoids elsewhere in the same structural zone (Sanandaj-Sirjan metamorphic zone), also have been reported (Hassanzadeh et al. 2008).

In this study U-Pb Laser Inductively Coupled Mass Spectrometry (LA-ICPMS) dating of zircons and Monazites used in order to find the ages of deposition and metamorphism of metasedimentary rocks in SMC.

Geological setting

The area NW of Takab in Sanandaj-Sirjan metamorphic belt of Iran (Fig 1a) consists of sedimentary units and Soursat Metamorphic Complex. The complex is positioned above the Takab-Shahin Dezh road (Fig. 1b) and presents tectonic contact with sedimentary rocks. Two main geological units have been described for Precambrian to Paleozoic sedimentary rocks (Kholghi khasraghi, 1994): (1) upper Precambrian Kahar formation consisting of slate, sandstone and some acidic volcanic rocks those locally reveal a very low metamorphic grade, and (2) Precambrian-Cambrian and Ordovician dolomite (Bayandor and Soltaniyeh formations), sandstone, shale and dolomitic limestone (Barut, Zaigon, Lalun and Mila Formations).

SMC is mainly composed of metamorphic rocks with associated granitic intrusions. Metamorphic rocks vary from greenschist to amphibolite facies and consist of mica-schist, garnet-schist, staurolite-schist, andalusite-schist, marble, gneiss and granite-gneiss Haghipour, 1974 & 1981. Geological aspects of the complex described by many authors (e.g. Alavi-Naini et al, 1982; Kholghi khasraghi 1994; Jamshidi, 2001; Ghasemi, 2001; Kholghi Khasraghi, 2004; masoudi et al, 2006; Modjarad 2007; Ghasemi et al, 2009; Jamshidi et al, 2009).

Result and discussion

ICP-MS dating of Zircon and monazite crystals in two schists were obtained based on following basics. Zircons were separated using conventional methods that include crushing, sieving, magnetic separation and floatation. More than fifty zircon grains were handpicked under a binocular microscope. The zircons were then set in synthetic resin mounts, polished and cleaned in a warm HNO_3 ultrasonic bath. Cathodolumuniscence (CL) and back-scattered electron (BSE) imaging were carried out to help characterize any compositional variation within individual zircons. Equipment and operating conditions for zircon analysis were identical to those reported by Payne et al. (2006). A spot size of 30 μm and repetition rate of 5 Hz was used for U–Pb data acquisition, producing a laser power density of ~8 J/cM2. Zircon ages were calculated using the GEMOC GJ-1 zircon standard to correct for U–Pb fractionation (TIMS normalization data $^{207}Pb/^{206}Pb$=608.3 Ma, $^{206}Pb/^{238}U$=600.7 Ma and $^{207}Pb/^{235}U$=602.2 Ma — Jackson et al. (2004)), and the GLITTER software for data reduction

(Van Achterbergh et al., 2001). Over the duration of this study the reported average normalized ages for GJ-1 were 609±10, 600.2±2.7 and 601.9±2.4 Ma for the $^{207}Pb/^{206}Pb$, $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ ratios, respectively (n=24).

Metamorphic monazite from sample Sh-68 was imaged using backscattered electron imagery (BSE) and conducted by LA-ICPMS at the University of Adelaide. Equipment and operating conditions for monazite analysis are identical to those reported by Payne et al. (2006, 2008). U– Pb acquisition utilised 10 μm beam diameter for monazite run at a repetition rate of 5 Hz. Monazite ages were calculated using the MADEL monazite standard to correct for U– Pb fractionation (TIMS normalisation data: $^{207}Pb/^{206}Pb$=490.7 Ma, $^{206}Pb/^{238}U$=514.8 Ma, $^{207}Pb/^{235}U$=510.4 Ma: Payne et al. 2008), and again the GLITTER software for data reduction. Over the duration of this study, the reported average normalised ages for MADEL are 493.0+8.3, 514.3+2.4 and 511.2+2.0 Ma for the 207Pb/206Pb, 206Pb/238U and 207Pb/235U ratios, respectively (n=32). Accuracy was monitored by repeat analyses of the in-house internal monazite standard (94–222/ Bruna-NW: $^{206}Pb/^{238}U$=447 Ma: Payne et al. 2008). Over the duration of this study, the reported average 206Pb/238U age for the internal standard was 446.9+3.1 Ma (n=15).

U/Pb dating of zircon from a staurolite-schist by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) yielded a maximum depositional age of 605±43 Ma (238U/206Pb). Based on U/Pb dating of zircon, metasedimentary protoliths of the Soursat Complex are interpreted to be deposited at the same time as the surrounding essentially unmetamorphsed Precambrian-Cambrian sedimentary rocks. One group of granitoids in the complex also has Ediacaran-Cambrian age (Jamshidi Badr et al, 2009a). The same age for deposition of SMC protoliths and emplacement of a set of granitoids and sedimentation of surrounding essentially unmetamorphsed rocks support recent interpretations of researchers working elsewhere in Iran and SE Turkey in recognizing an active margin developed along this part of the Gondwanan margin (Ramezani & Tucker, 2003; Ustaomer et al. 2009) immediately after Gondwana amalgamated (Collins & Pisarevsky, 2005).

Monazite were also dated from a garnet-schist yielded a $^{238}U/^{206}Pb$ age of Palaeocene-early Eocene that could be interpreted as the time of the peak of regional metamorphism, U-Pb zircon data from another group of granitoids also yielded Palaeocene-early Eocene crystallization ages (Jamshidi Badr et al, 2009a). Regional metamorphism occurred later and it could be related to the Paleocene orogenesis during the collision of Arabian plate with Iranian block and closure of Neotethys.

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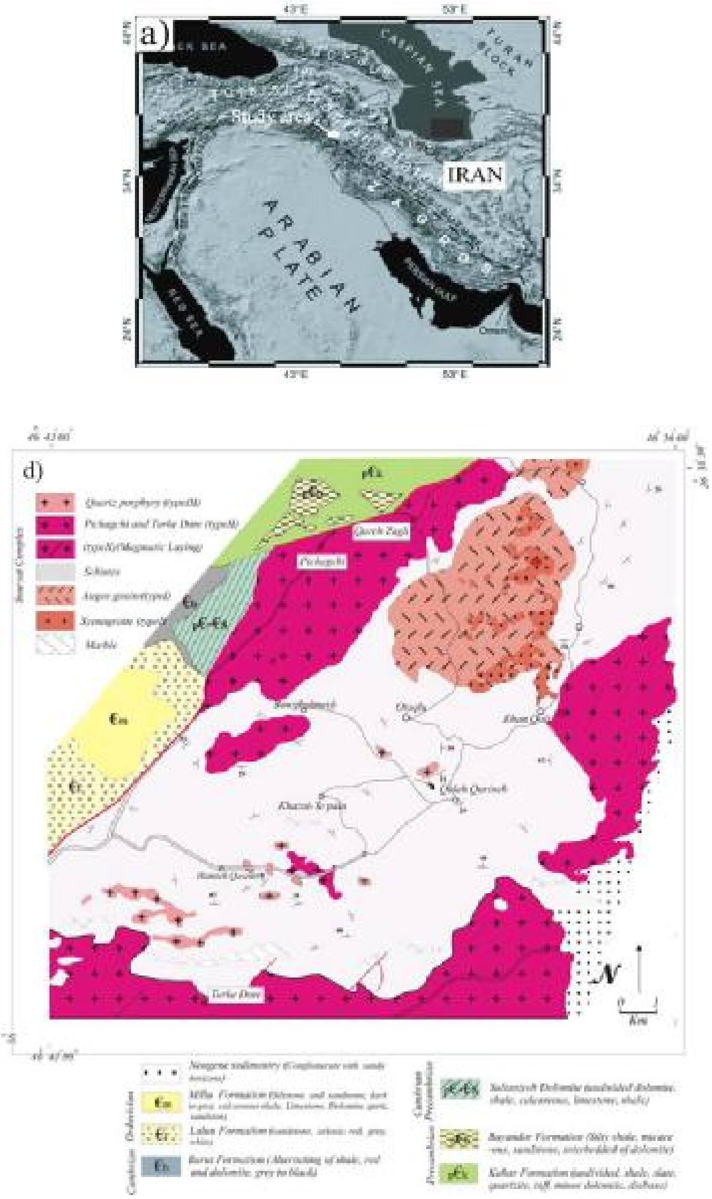

Fig 1: a) Geologic map of Iran and surrounding regions showing mountain belts, Zagros fold-thrust belt (after Guest et al., 2006b). White circle indicates study area. b) Geological map of the Soursat region, with position of granitoids suites in Schist countryrocks, and the sedimentary rocks.