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Bibliographic description of researches on Makran geology, unbreakable link between Iran and Pakistan

Abstract

Makran East-West trend expanded in two countries of Iran and Pakistan. The geological characteristics of this zone attract the geologist's attention from long time ago. The length of this plain is about 900 km and its width is around 300 km that situated in land. Major studies has been started since 70s and continued by different geologists around the world to the present time. Key studies related to the systematic researches that contain the total area of Makran caused providing the Makran's geological reports or the Seismic profiles of the seabed Oman. In these studies the situation and tectonic position of Makran and also the direction and rate of relative motion of Arabian plate and Oman sea to the north becomes clear and has effects on diverse kinds of analysis such as neotechtonics, raised beaches, sediment deformation style, folding and magmatism in Makran. Extent and variety of geological issues on Makran's studies caused to consider the related researches in six major categories such as " General studies

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on geology", " Tectonic and structural studies", " Geophysical studies", " Seismicity studies", " Mineral and Hydrocarbon studies" and "Neotectonics and Raised beaches studies".

Keywords: Makran, Iran, Pakistan, Bibliography, Geology, Seismicity, seismic profile, Hydrocarbon, Marine terraces.

Introduction

Makran zone is one of the unique mountain ranges of the world that formed during the especial geological processes. Part of the Makran's mountain ranges positioned in Iran and the other part continued in Pakistan with an east-west trend. Western borders of the Makran's mountains limited to Minab fault in Iran and the eastern borders restricted by Ornach-Nal fault, that it is extended about 900 km from west (Iran) to east (Pakistan). The north border reaches to Jazmoorian depression and enters Pakistan towards east after confluence with Sistan's suture zone in Zaboli region and Soran with Zaboli fault. Although the southern range of this zone is limited to Oman seacoast, the folded sediments of Oman seabed, minimum of 150 km to southern coast, shows the width of Makran is over 300 km in the land. According to geological studies, Makran is the product of compressing and folding the Oman seabed sediments. These Sediments have been added (Arshadi & Forster 1983), together like accretionary prism from at least Late Cretaceous till now (White & Klitgord 1976, Farhoudi & Karig 1977). In addition, part of the sediments has emerged from the water which we know it as the Makran. The tectonic model of the area is similar to many areas of the world such as Eastern Pacific Margin that has created the current active continental margins. However, what distinguishes the Makran with these areas is that the Low-angle subduction is below one degree (White & Klitgord 1976). The subduction with Low-angle has been continued under folded Makran and caused the accretionary prism formation with large expansion which discriminate this region from similar areas. The accretionary prism in Iran, started from Jazmoorian depression margins, has been continued to Oman coast and folded about 150 km into the sea. According to Jacob & Quittmeyer opinion (1987), distance of volcanic arc and the Oman Sea Trench is intended 500±100km (arc-trench gap). This extraordinary expansion in both onshore and offshore has doubled

its geographic characteristics. This area of particular geological and geographical extent of the two countries, Iran and Pakistan may require up to collect several investigations and geological research that have been carried out so far in this range, to be a basis for subsequent studies. Nevertheless, the author admits that this article have not considered the set of all those which has come to this area. A great deal of research in this area will oblige us to have only a glimpse on those subjects.

Makran zone Geology

Extensive Makran's zone, has led to various Geological topics whereas in order to observe a short article, this zone has been divided into six major categories and various text related to those will be introduced as:

1. General studies on Makran's geology
2. Makran tectonic and structural studies
3. Geophysical studies of Oman seabed
4. Makran's seismicity studies
5. Makran's ore deposits and hydrocarbon studies
6. Makran's neotechtonics and raised beaches studies

1. General studies on Makran's geology

The systematic studies of Makran region of Iran is related to the research company Paragvn, which has been listed in the north Makran and sought Baluchistan's reports (McCall et al. 1985a). Additionally the reports of 1:250000 geological maps of these regions have been published by geological survey (Samimi Namin et al. 1983, McCall et al. 1985b, McCall et al. 1985c, McCall & Eftekhar Nezhad 1993, McCall et al. 1993, McCall 2002 ؛ Samadian 1356 ؛ Samadian 1372-1378). Furthermore, The 1:250000 maps of Pakistan's Makran zone and some of the 1:50000 maps of east Makran have been published by Pakistan's geological survey (Pakistan geological website). Kazmi and Qasim Jan also has developed a book about the geology and tectonic of Pakistan in 1997.

According to the plate tectonics theory It is believed that the subduction of Arabian Plate process (Oman Oceanic crust to the north) in Makran zone (DeMets et al. 1990, Nakata et al. 1990, Vernant et al. 2004) is the reason of flysch facies and ophiolite melange formation (White & Klitgord 1976, Farhoudi & Karig 1977, White 1977, Jacob & Quittmeyer 1978, Platt et al. 1985, Minshull & White 1989, Sarwar 1992, McCall 1995, 1996, 1997, Mahmood et al. 1995). According to the Upper Cretaceous-Paleocene sediments deformation, addressed the beginning of this process to Cretaceous-Paleocene (Arthurton et al. 1982, McCall & Kidd 1982, Arshadi & Forster 1983, Robertson et al. 1990, Gnos et al. 1997). However, some geologists state the first encounter and collision of the oceanic crust of Neotethys in the Middle Jurassic (Haynes & Reynolds 1980, Farah et al. 1984). On Stratigraphy and tectonic evolution of the Zagros and Makran, a book has been developed with different proceedings that a few sections are related to the evolution of Makran (Leturmy & Robin 2010). Geological studies has been done on various topics of Makran zone that each study encompasses part of this zone (Falcon 1968؛ Ahmed 1969). Turbidite facies development is the main features of the lithology of these areas that have been referred by many (Critelli et al. 1990, McCall 1994,Luckge et al. 2002, Schultz et al. 2002, VonRad et al. 2002, Szuman et al. 2006, Bourget et al. 2009, Bourget et al 2010).

2. Makran tectonic and structural studies

History of tectonic and structural changes of Makran and its range in Pakistan and Iran has led to encourage many geologists discussed about tectonic developments in this area (Hatchison et al. 1981, Arthurton et al. 1982, Leggett et al. 1984, Platt et al. 1985, Platt et al. 1988, Robertson et al 1990, Davis et al. 1994, Khattab 1994, Garzanti et al. 1996, Fruehn et al. 1997, McCall 1997, Ravaut et al. 1997, McCall 2003, Carter et al. 2010). The difference between Zagros tectonic-sedimentary history and Makran and on the other hand Indian collision with Asia, has engendered development of the shear zone on the border of this zone, like what be seen in Ornach-Nal and Minab fault zones. Moreover, shear zones influence the deformation that is seen in these parts (Minshull et al. 1992, Jadoon & Khurshid 1996, Macedo & Marshak 1999, Delaunay et al. 2002, Bayer et al. 2003, Smith et al. 2005, Ellouz-Zimmermann et al.2007a, Ellouz-Zimmermann et al.

2007b). Withdrawals of analyzing seismic data from the Oman seabed have made many geologists to have a new look on the morphotectonic phenomena of these parts (Kukowski et al. 2001, Uchupi et al. 2002, Mitchell 2006, Grando & McClay 2007). In addition, majority of the geologists talked about the origin of mud volcanoes in this area that can be caused by compressing the sediments and removal of water and gas from them (Fowler et al. 1985, Sain et al. 2000, Ellouz-Zimmermann et al. 2008, Calves et al. 2010).

3. Geophysical studies of Oman seabed

Deformation and folding of Makran zone is not unique to Makran Mountains. folding and Development of faults can also be seen in the Oman Seabed sediments. These deformations were better apparent when the geophysical studies and seismic interpretation of the seabed were prepared (Ahmed 1969, White & Klitgord 1976, White 1977, Jacob & Quitmeyer 1978, White & Ross 1979, White 1982, Kopp et al. 2000, Gaedicke et al. 2002, Mouchot et al. 2010). Seismic profiles show sediment deformation and Thrust faults development very good. Thrusts dip is mainly to the north and Synclines often have developed between the thrust faults (White & Klitgord 1976, White 1977, White&Ross 1979, Platt et al. 1985, Ravaut et al. 1997, Uchupi et al. 2002, Hosseini-Barzi & Talbot 2003, Hosseini-Barzi 2010). Seabed studies resulted to the nature of the major fractures such as Owen Fracture zone. This fracture zone located as a boundary among the Indian and Arabian plate. The effect of this fracture on the border of Pakistan and India is like Ornach-Nal and Chaman fault has appeared along it (Monem 1971, Auden 1972, Monem 1972, Lawrence et al. 1981, Grando & McClay 2007, Carter et al. 2010). On the studies of Grando and McClay (2007), the boundary between Indian and Arabic plates considered as Owen Fracture zone that reached Murray ridges in the north-west Indian Ocean and eventually appears Ornach-Nal in the East Makran inside Pakistan border. They also consider small plate called Ormara plate on the border of Makran accretionary prism and Murray ridges.

4. Makran's seismicity studies

Makran zone subduction process and its few centimetres movement to the north have caused a lot of faults and fractures to be formed in the suites of accretionary prism sediments (Little 1972, Vita-Finzi & Ghorashi 1978, Page et al. 1979, Verma et al. 1980, White 1984, Verma et al. 1986, Vita-Finzi 1986, DeMets 1990, McCall 1996, Heidarzadeh & Kijko 2010). The majority of these fractures are the imbricate faults that have developed parallel to general structures of Makran. Continuous process of subduction caused concentration of the energy in different parts of Makran, which its release in some stages has caused the earthquakes (Farhoudi 1977, Rowlands 1978, Page et al. 1979, Quittmeyer 1979, Quittmeyer & Jacob 1979, Niazi 1980, Niazi et al. 1980, Byrne et al.1992, Hosseini-Barzi & Talbot 2003, Khan et al. 2003, Mokhtari et al. 2008, Yaminifard & Hatzfeld 2008). Although the concentration of earthquakes in this area is not similar to the comparable regions and particularly the Zagros region. But, unrecording earthquakes in recent periods cannot associate an aseismic area (Eslami & Hassanzadeh 1365). The seismic studies around Chabahar and Iranshahr that has been done by Islami & Hassanzadeh from 1985 to 1986 (1365), shows that narrow Makran coast of Iran in the current century matches with the concept of a gentle and temporal seismic quicsence. Nevertheless, seismic activities in eastern Makran and the large Pasny-Ormara earthquake in this century, kept open the discussion about the earthquake seismicity in the Makran subduction zone (Islami & Hassanzadeh 1365). A number of tsunamis have been reported in Makran coast (Heidarzadeh et al. 2008, Heidarzadeh et al. 2009). Heidarzadeh et al.(2008) release some statements regarding to the historical tsunami of Makran subduction zone in Iran and Pakistan. In this paper, the relative motion of subduction has been noted as 19 mm/year in the North East and the history of shallow earthquakes have been identified. Lastly the various tsunamis since Dabhol tsunami in 1524 until the Makran tsunami in 1945 are investigated. Besides, in this paper, the origin of all tsunamis considers as Oman seabed earthquakes and north-West of Indian Ocean.

5. Makran's ore deposits and hydrocarbon studies

Makran Mountain Structure is in such a way that most of the igneous rocks centered like the narrow ophiolite on the north sidelines (Delaloye & Desmons 1980, Athurton et al. 1982, Arshadi & Forster 1983, Desmons & Beccaluva 1983, Zigham & Mallick 2000, Ghazi et al. 2004). Ghazi et al.(2004) discuss Chemical features and tectonic position of Bande-Ziarat and Daranar ophiolite in north-west of Makran, and consider the age of formation of ophiolites in this area as the late Jurassic - Early Cretaceous, based on radiogenic age determination. The concentration of chromites ore has been reported mostly on this strip. On the contrary, the process of subduction oceanic crust has caused volcanic like, Bazman, Chah shahi, Taftan and Sultan in the northern part of Makran and many important anomalies minerals such as copper is seeking in the following areas (Brouse & Moin-Vaziri 1980, Nicholson et al. 2010, Perello et al. 2010, Shahabpour 2010). Magmatism from the subduction processes usually shaped with a distance from the belt of accretionary prism. Therefore, it seems many igneous masses which caused by the Makran subduction, have been occurred at other zones like Lut rims, Nehbandan- Khash area or Chagai's belt in northern Pakistan. Regarding to this Hou et al.(2010) in the article, examines the porphyry copper belt in East Tethys, which refers to the copper belt in Kerman region in Sahand-Bazman zone in Iran and Chagai copper belt in the West Pakistan.

In addition to minerals that are mostly the product of igneous rocks in these areas, Hydrocarbon formation is considerable in this zone. Although deformation of accretionary prism sediments in the Makran has not allowed that a proper and a large anticline, like what is seen in the Zagros formed. But the presence of widespread mud volcanoes in the Makran coast of Pakistan and Iran indicates Hydrocarbon gases concentration in accretionary prism (White 1979, Harms et al. 1984, Fowler et al. 1985, Minshull & White 1989, Khan et al. 1991, von Rad et al. 1996, Robison et al. 1999, Sain et al. 2000, von Rad et al. 2000, Wiedicke et al. 2001, Delisle et al. 2002, Schluter et al. 2002, Delisle 2004, Delisle 2006, Ellouz-Zimmermann et al. 2008, Ghosh & Sain 2008, Negaresh 2008, Ojha & Sain 2008,Calves et al. 2010, Morely et al. 2011).

6. Makran's neotectonics and raised beaches studies

The active process of the Makran zone can be seen during the Quaternary at the formation of marine terraces in these regions that indicate the young tectonic activities in Holocene and Pleistocene (Little 1972, Page et al. 1979, Vita Finzi 1979, Samadian 1982). These terraces are seen from Jask to the coast of Pakistan. According to surveys conducted, the rate of uplift of the western coast of Makran increased to the East Coast and reaches to a maximum of about 2 mm per year (Little 1972). Remaining terraces reach at 5 to 6 meters in Jask, upper limit to 105 m in Konarak area (Page et al. 1979) and 201 meters above sea level in Ras-Kapar (Pakistan) (Ahmed 1969). The existences of marine terraces represent that these regions been active and seem to continue the tectonic activities of prior periods (Snead 1970, Snead 1993, Kukowski et al. 2001). Page et al. (1979) are considered the Makran marine terraces as the result of the large earthquakes. According to their understandings the 1945 earthquake, 3.8 M Pasni and Ormara caused uprising the marine terraces about 1-3 meters in this region.

Conclusion

It is the foundation of scientific research that already conducted in different fields and each new study is founded based on past researches. A researcher can investigate the issue properly, when finds a general vision on a comprehensive overview of the background study and avoid the replicates and retrogression. This study has tried to provide as much as possible of this collection for geological researchers who are interested in Makran problems and think about their solutions.

The collection will be more complete when it can be formed a single database. Variety of databases, journals and international diversity, the existence of research databases and lack of access to all of them more apparent the essential of this issue. Although in different fields discussed in this article have been many investigations, but it seems some fields, such as Makran's raised beaches and Neotectonics has been neglected for some time. It is hoped the young geologists compensate the research gap with more effort in future.

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