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ISBN: 978-622-5858-45-9

2023

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Geology and Structural Analysis in Bushehr Peninsula

UCCGHA 007

2023

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سرشناسه :	شکری، محمدعلی، ۱۳۵٦ -Shokri, Mohammad Ali, 1977
عنوان و نام پدیدآور :	Geology and structural analysis in Bushehr peninsula[Book]/ authors Mohammad Ali Shokri, Aram Fathian; employer Research Institute for Earth Sciences; advisor Geological Survey of Iran; with cooperation UNESCO Chair on Coastal Geo-Hazard Analysis; summarized and translated into English Manouchehr Ghorashi.
مشخصات نشر :	تهران: نشرخزه، ۱۴۰۲= ۲۰۲۳م.
مشخصات ظاهری :	۲۶ص.: نمودار؛ ۱۴ × ۲۱ سم.
شابک :	978-622-5858-9-45
وضعیت فهرست نویسی :	فیپا
یادداشت :	زبان: انگلیسی.
یادداشت :	عنوان به فارسی: زمین شناسی و تحلیل ساختاری در شبه جزیره بوشهر.
موضوع :	زمین‌شناسی -- ایران -- بوشهر
موضوع :	Geology -- Iran -- Bushehr
شناسه افزوده :	فتحیان، آرام، ۱۳۶۲-
شناسه افزوده :	Fathian, Aram,1983-
شناسه افزوده :	قرشی، منوچهر، ۱۳۲۰-، مترجم
شناسه افزوده :	Ghorashi, Manouchehr- 1941-
شناسه افزوده :	یونسکو. کرسی مخاطرات زمین شناختی ساحلی
شناسه افزوده :	UNESCO Chair on Coastal Geo-Hazard Analysis
شناسه افزوده :	سازمان زمین‌شناسی و اکتشافات معدنی کشور. پژوهشکده علوم زمین
شناسه افزوده :	Geological Survey of Iran, Research Institute for Earth sciences
شناسه افزوده :	سازمان زمین‌شناسی و اکتشافات معدنی کشور
شناسه افزوده :	Geological Survey of Iran
رده بندی کنگره :	QE۳۰۷
رده بندی دیویی :	۵/۵۵۵
شماره کتابشناسی ملی :	۹۳۶۲۹۴۱

Geology and Structural Analysis in Bushehr Peninsula

Author: Hamid Nazari

نشر خزه

اطلاعات گزارش

عنوان: زمین شناسی و تحلیل ساختاری در شبه جزیره بوشهر

مجری: پژوهشکده علوم زمین

مشاور: سازمان زمین شناسی و اکتشافات معدنی کشور

زبان مرجع: فارسی - انگلیسی

خروجی: گزارش، نقشه، مقاله، داده های الکترونیکی

ناظر علمی: حمید نظری

نویسندگان: محمدعلی شکری، آرام فتحیان

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مسئول شورای اجرایی: راضیه لک

خلاصه‌نویسی و ترجمه به انگلیسی: منوچهر قرشی

ناشر: نشر خزه

با همکاری کرسی یونسکو در مخاطرات زمین شناختی ساحلی

چاپ اول: ۱۴۰۲

شمارگان: ۵۰ نسخه

صفحات: ۲۶

شابک: ۹۷۸-۶۲۲-۵۸۵۸-۹-۴۵

khazepub@gmail.com

Report Information

Title: Geology and Structural Analysis in Bushehr Peninsula

Employer: Research Institute for Earth Sciences

Advisor: Geological Survey of Iran

Original language: Persian- English

Output: Report, Map, Paper, Digital Meta Data

Supervisor: Hamid Nazari

Authors: Mohammad Ali Shokri, Aram Fathian

Chairholder in the UNESCO Chair on Coastal Geo-Hazard Analysis:
Hamid Nazari

Head of the Executive Council: Razyeh Lak

Summarized and translated into English: Manouchehr Ghorashi

Publisher: Khazeh Publication

with cooperation UNESCO Chair on Coastal Geo-Hazard Analysis

First Edition: 2023

Edition number: 50

Page: 26

Shabak: 978-622-5858-9-45

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Abstract

The present research in the Fars area and in the Zagros fold-and-fault structural zone with the aim of structural analysis, investigation, assimilation and updating of faults with regard to their structural relationship to folds and anticlines of the region has been completed. In these studies, which are based on pre-existing data, an attempt is made to widely use all the published data, such as geological maps on the scales of 1: 250,000 and 1: 100,000, SRTM digital elevation data with spatial accuracy of 90 and 30 meters, Landsat and SPOT satellite images with 15 meters accuracy, as well as digital 1: 25,000 topographic maps data.

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In 1973, Stocklin and Nabavi published the first tectonic map of Iran based on the information of the

National Iranian Oil Company and the Geological Survey and Mineral Exploration of Iran. These authors subdivided Iran into 10 structural zones based on certain geological characteristics. These structural subdivisions have been used as a reference in the last three decades by Iranian geologists. However, new observations and findings indicate the need to review these structural zones. After the structural zones presented by Stocklin and Nabavi, other structural divisions have been presented, especially in the Central Iranian structural zone. Of course, all these models are prepared based on the initial model provided by Stocklin. In recent years, new interpretations and new models have been presented in the field of the geological setting of Iran (Nabavi, 1976, Eftekharnejad, 1981, Nogol Sadat, 1993, Alavi, 1994, and Aghanabati, 2004). What follows is a composite summary of the available data from the Zagros zone:

The Zagros mountain belt is located in the southwest of Iran. This mountain belt has a northwest-southeast trend and its length is about 1700 km. The Zagros starts from the eastern part of Turkey and Iraq and continues to Oman and the Makran mountains in the south of Iran and is one of the main parts of the Alpine-Himalayan orogenic belt. The width of Zagros is between 250 and 350 km. This mountain belt is one of the largest fold-and-thrust systems in the world and is considered one of the most important oil states in the Middle East. Compared to the Alps and the Himalayas, the Zagros mountain range has a lower height. In Zagros, the average height is 1200 meters, and there are several peaks of 3500 meters in different parts of it. This mountain belt in the south-western part of Iran separates the low-altitude lands of the Persian Gulf-Mianrudan in the Arabian block from the high block of Iran in the north-eastern part. (Nazari et al, 2019).

This mountain belt is the result of the collision between the Arabian and Iranian continental blocks during the Cenozoic Era, after which an important deformation has occurred in the deposits of the passive margin of the Arabian block. The young geological age of the Zagros collisional belt in the dry and sparsely vegetated areas exceptionally preserves and reveals the folded and faulted structures and is a suitable factor in the geometric and kinematic analysis of the collision zone data. Also, the Zagros mountain belt is considered as one of the important regions in the world in terms of deformation. Therefore, this mountain belt is considered as a natural laboratory for the studies of old stages of deformation and changes of kinematic regimes during collision stages in passive continental margins (Nazari et al, 2019) (Figure 1).

Introduction:

The study area is a small part of the Zagros structural zone. The stratigraphic investigation in this area shows that in this part of Iran, there are outcrops of sedimentary rocks of Triassic to Quaternary ages. Since the Middle Triassic, with the development of the young Tethys Ocean, special marine conditions have ruled this tectonic realm. From the Late Cretaceous onwards and after the evolution of the young Tethys Ocean and the early stages of collision between the Arabian and Central Iranian blocks, the conditions governing the sedimentary environments changed and the shallow-to deep marine deposits were formed. During the Paleogene, the marine and non-marine deposits were accumulated in the foreland basins at the same time as the Alpine orogeny and in a regressive sea towards the southwest (Nazari et al, 2019).

Geographical setting:

Bushehr peninsula is connected to the surrounding cities through 4 main ways:

Bushehr - Khormoj - Kangan - Bandar Lengeh - Bandar Abbas, 920 km in length

Bushehr - Borazjan - Shiraz, 290 km in length

Bushehr - Borazjan - Yasouj - Isfahan, 610 km in length

Bushehr - Genaveh - Bandar Deylam - Mahshahr – Abadan, 690 km in length

The route from Bushehr to Borazjan is freeway and the rest of the routes are round-trip roads.

Methods:

In order to prepare geological maps on the scales of 1:100,000 and 1: 50,000, Bushehr area has been used. Geological maps have been digitally prepared based on the description of the contract services in the form of 6 subjects and on the scales of 1:50,000 and 1: 25,000 (Nazari et al, 2019).

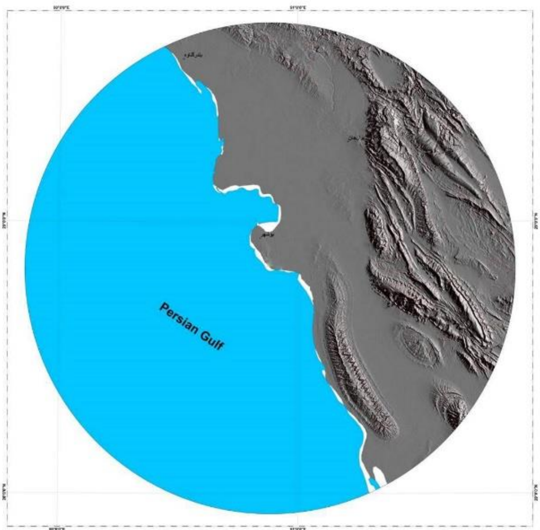

Figure 1: Map of the height and geographical location of the study area within a radius of 100 km from Bushehr (Nazari et al, 2019).

Discussion:

With a general look to the situation of the study area on the prepared structural map, it is clear that this area has folded and faulted structures like other areas of Zagros. By looking at the geological maps previously prepared on the scales of 1:100,000 and 1:250,000, this issue can be clearly identified. With this introduction, in the following, first the folded structures and the faults ruling the region are presented in the form of the surface structures and then a brief description of the subsurface structures are provided.

Folded structures: considering that the study area is located on the Zagros folded zone, in a special type of division, the most important structures of the area are folded and less faulted. Anticlinal structures are more clearly visible, but synclinal structures are less clear.

Anticlines are one of the most basic exposed structures in the study area. Their axial extension is northwest-southeast, which follows the general trend of the Zagros Mountain Ranges. Among the anticlines of the region, it can be mentioned Asan, Bozpar, Giskan, Bushkan, Siah, Chah Pir, Khartang, Shirkuh, Khormoj, Kaki, Namaki and Mond (Nazari et al, 2019) (Figure 2).

Figure 2: Representation of local anticlines in the Gachsaran Formation in the southeastern plunge of Giskan anticline, the fold axis has a northwest-southeast trend, which indicates compressional forces with a northeast-southwest trend.

In the north of Bushehr, there are many anticlinal and synclinal structures, and small folds in the evaporate rocks of the Gachsaran Formation. Gypsum layers, due to the diversity of the layers and the change in their thickness, have had a tremendous effect on the mechanism of folding and its geometry, especially in the zone of fold hinge, and it has acted as one of the decollement surfaces in the study area. In these areas, the main form of fold is controlled by resistant units, but the presence of weaker units can also have unforeseen effects on the form of fold and the structure of the area.

The Gachsaran Formation can be an important decollement surface in the study area, with lateral changes of facies and thickness, causing changes in the wavelength, amplitude and fold style.

Also, in places where these unconformable surfaces are active in folds, the surface structures do not necessarily match the deep structures. Due to the constant, uniform and a few centimeters thickness of the layers, the folds are mostly as parallel folds. A variety of fold accommodation faults have been created in the continuation of folding. The investigation of the geometry and mechanism of folding in these deposits indicates that deformation took place in the Gachsaran Formation by creating semi-symmetrical folds with a buckling mechanism and with a vergence to the south-southwest. (Nazari et al., 2019).

On the southern limb of the Kuh-e Siah anticline, the layers of different units are folded due to faulting. Among these folds, it can be mentioned the folds in the medium-bedded limestones of the Sarvak Formation.

The fault structures in the study area are present in three categories of strike-slip, thrust and normal faults. Faults often extend from northwest to southeast, but faults with east to west trends are also observed. Also, the dip of the fault is different in various faults.

By looking at the available maps in the area under investigation, we find out that the time period of the activity of different faults is, finally, until the time of the formation of the Asmari Formation. In post-Asmari Formations such as Gachsaran, Aghajari and Bakhtiari Formations, less fault activity is observed. Open and symmetrical folds can only be observed in the evaporites of the Gachsaran Formation (Nazari et al, 2019).

According to the maps that have been prepared recently, it can be seen that many of the existing and surveyed faults have little influence on the structural destiny of the investigated area and are often local.

In the Mesozoic and Paleogene Formations, due to their place of formation, which is at the edge of the passive margin of the Arabian block, the presence of syn-sedimentary normal faults has caused a thick succession of limestone Formations to be observed in the Mesozoic and Paleogene periods. By field studies, the evidence of this faulting can be found everywhere in this rock complex. Also, some normal faults were formed in the condition of folding at the same time as the Zagros orogen. These faults have caused the formation of horst and graben structures in the studied area. Also, most of the landslides on the limbs of the anticlines are caused by gravity and by normal faults.

Geological maps on a scale of 1:100,000 are the main layers of basic information in every country, which are widely used in all development, civil, industrial, etc.

projects. Geological maps are considered as the main basic information in the studies of earthquakes, landslides, volcanoes, natural hazards, etc. 1:50,000 scale geological maps have been the basis of all civil and development projects in recent years. These maps were prepared based on large-scale topographic maps (Nazari et al, 2019).

Based on the studies and stated needs in the preparation of different layers, geological maps on a scale of 1:100,000 within a radius of 100 km from the site and geological maps on a scale of 1:50,000 within a radius of 50 km from the site were prepared in 6 layers, which are:

• Regional geological map for an overview of the geological situation of the region

• Simplified geological map in order to check the condition of outcrops in the area without considering the age and type of rocks

• Geological maps based on the differentiation of rock units to determine the potential of borrow pits in the region

• Geological maps based on structural units to determine the general structure of the region

• Geological maps based on Quaternary and pre-Quaternary units to determine the status of Quaternary sedimentary basins and show the expansion of waterways, rivers, etc.

• Comprehensive geological maps of pre- and post-Quaternary units to display all geological units

• Preparation of 6 structural sections based on prepared geological maps (Nazari et al, 2019).

Conclusion:

The Bushehr anticline is the youngest, frontal-most deformed, onshore structure within the Zagros orogen. This study focuses on the tectonically active structures within the Bushehr plain, SW Iran, using tectonic geomorphology, remote sensing, and Quaternary geochronology.

Our field observations along the coasts of the Bushehr Peninsula confirm the laterally ascending and/or descending variations of the marine terraces in terms of elevation. These observations in addition to the topographic profiles across the Bushehr anticline, mark the asymmetry of the limbs and reveal the significant role of tectonics in uplifting the risers. Two stages of tectonic events within the Bushehr anticline are identified. The cap-rock and the lower units are separated by the angular unconformity at the level of Late Eocene. The entire underlying series is tilted significantly steeper than that of the younger Oligocene-Quaternary strata.

Our studies led to the identification of some new active faults in the studied area, namely the Bushehr, Abtavil, and North Bushehr faults. In the southeast of

Bushehr, a short zone of young fault branches—herein termed as the Kharg Mish fault with a length of ca. 4 km—consistent with the Bushehr anticline axis, which seems to be an outcome of the Bushehr anticline growing due to the Bushehr fault activity.

The Kharg Mish fault is aligned with the Kharg fault marking the N-S-oriented Kharg lineament within the Bushehr plain, a concealed fault has been inferred, termed as the North Bushehr Fault, southwest of the Abtavil Anticline. The Abtavil anticline is more likely a fault-bend fold and the Abtavil fault is the fore-thrust northeast-dipping fault uplifting aeolian deposits and sand dunes on its hanging wall, while lacustrine and playa deposits exist on the footwall. These playa deposits are young with an age of approximately 0.15 ka.

However, the alluvial flood deposits with an age of about 1.8–2.0 ka lie farther to the southwest of these deposits bounded by the North Bushehr fault. Compared with the flood deposits, the young playa deposits have been clearly uplifted, and apparently, a variation in the gradient occurred in this area due to the activity of the North Bushehr fault.

The N-S strike-slip faults appear to be fewer in number relative to the compressional faults within the study area, however, they actively involve the current deformation in accordance with the evidence of instrumental and historical seismicity. (Nazari et al, 2019).

The largest strike-slip fault in the study area—the Borazjan fault—has a clear expression on both satellite imagery and topographic data. Several folds on the eastern block have been terminated or truncated by this fault. The earthquake epicenters are linearly aligned north-south close to this active structure. The fault splays off to thrust fault dipping to the north at its southern end, along the Khormoj anticline. It seems that the southern limb of the Khormoj anticline is overturned due to the activity of the fault.

We observed and documented geomorphic markers associated with young tectonic activity within the Bushehr plain and, to the southwest, offshore of the Bushehr Peninsula (Nazari et al, 2019).

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