Research Article

Lineament Fabric of South Baluchistan (Iran) and its Impact on Geomorphic Landforms

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Abstract

Lineament analysis of South Baluchistan region in Iran using sensors of Landsat 8 (Landsat Data Continuity Mission, LDCM)) suggests orgoenic uplift of the region brought about deformation of mesoscopic structures. The lineament fabric showed prominent lineament directions along E-W and NW-SE. The study also revealed that the Alpine Himalayan orogenic uplift has been responsible for the structural fabric of the south Baluchistan. This deformation is documented in the form of reverse and normal faults.
Keywords: Landsat 8, lineament, GIS, Baluchistan, Remote Sensing, faults.

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INTRODUCTION

Landsat imageries have been used in the present study for detecting geological structures. The availability of multi-spectral and high-resolution data and advanced digital image processing techniques has further enlarged the potential of remote sensing in delineating the lithological contacts and geological structures (Drury, 1987 and 1993; Carrara and Pike, 2008). Earlier, such study has been carried out by Carrara *et al*., 1990; Ghahramani, 2010 for interpreting regions of Afghanistan and Iran to analyse the tectonic and geomorphological complexity. Abrams, 1984 has used optical and Radar-optical data (SRTM) to discriminate various lithologies, lineaments and minerals by using hyper spectral characteristics. The spectral enhancement techniques were used to extract the initial geological information and based on these, lithological characterization was possible. The directional filtering techniques have allowed the delineation of the lineaments in the region. The patterns recognized in the digitally processed satellite images assisted in extracting the initial lithological contacts and structural lineaments. Further, these patterns were used as a base for generating geological and structural maps through visual interpretation. The usage of data received from Landsat 8 (Landsat Data Continuity Mission: LDCM) was very handy as it provided the longest continuous record of the Earth's surface as seen from space. Landsat 8 LDCM differs from its predecessor Landsat 7 ETM+ with the addition of 2 new spectral bands; Coastal Aerosol (band 1), designed to investigate water resources and coastal zones, and Cirrus (band 9), a new infrared channel for the detection of cirrus clouds.

Study area

The area of investigation lies in the southeast of Iran and extends for about 250 kms from Minab fault in the west to the border of Pakistan towards east. It encompasses low-lying flat terrain to highly undulating hilly ranges. The lowest elevation observed is about 5 m above sea level and the highest relief is at 850 m in the northern part. This area is very poorly vegetated. The mountains are bare, rocky and the topography is covered only by sparse scrubs, grasses, bushes and stunted trees.

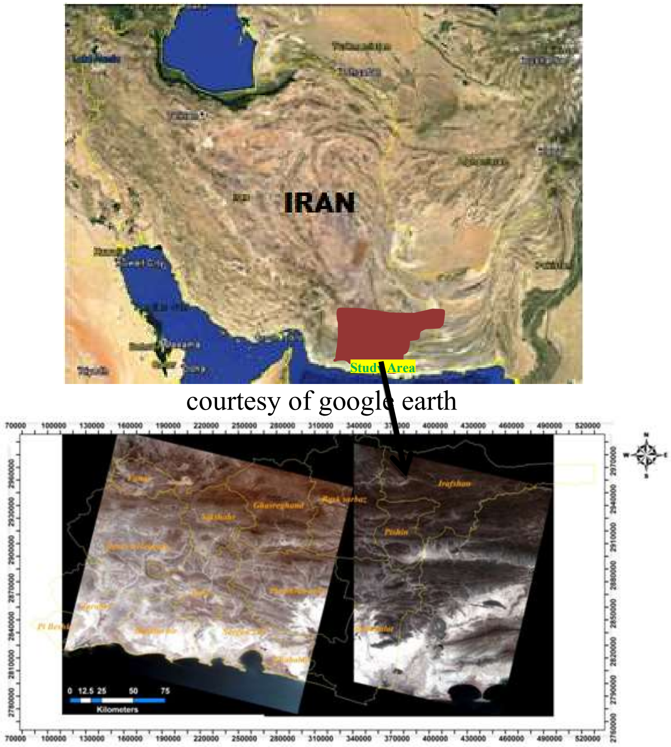

Figure 1: South Baluchistan area, Fused bands 1, 2 and 3 of Lands at 8

GEOLOGICAL SETTING

As a part of Makran ranges, this region is a vast tectono-metallogenic zone in southeast of Iran (Khan *et al.*, 1998). The region is studded by minor and major folds and faults. The older formations were observed towards north while younger sediments are located in the southern region. Huge thickness of Paleocene-Neocene flysch sediments include shales, sandstones, silt and marl, which have been folded on small scale, and are traversed by several fractures. The surface exposed sediments are mainly conglomerates, that cover a large area and with a thickness of two to three meters. These are mainly constituted of pebbles and sand, without much cement and therefore, have relatively good permeability (Stoklin and Nabavi, 973). Alluvium within the river basins is formed mostly by pebbles mixed with clay, which also make good aquifers. Alluvial flood plains, also covering a large area, include mainly clay and silt, which are impermeable (Yousefi, 2014). Hence, there are no commercial aquifers in the regions where they dominate (northern parts of south Baluchistan) and have poor grain size distribution (Stoklin and Nabavi, 1973). Sediments in the study area are divided into two groups. The first group consists of scree or shales and sandstones, which account for highland weathering and transportation in valleys and stream beds in mountains areas. These horizons possess medium permeability but have no reasonable thickness (Yousefi, 2014). The other group of alluvial sediments is located along coastal plains which represents transported stream channel deposits and also deposition along the coastal zones. The weathering of this area has resulted into fine grain sediments with a thin veneer. These sediments have developed delta deposits. In contrast, the recent alluvial sediments are coarse grained and occur within the river beds (Darvishzadeh, 1997; Agha, 2004 and Yousefi, 2014). Sedimentary Mélange is a structural unit, produced by tectonic dislocation of the flysch sequences, in which stratigraphic continuity is obliterated (McCall, *et al*., 1985).

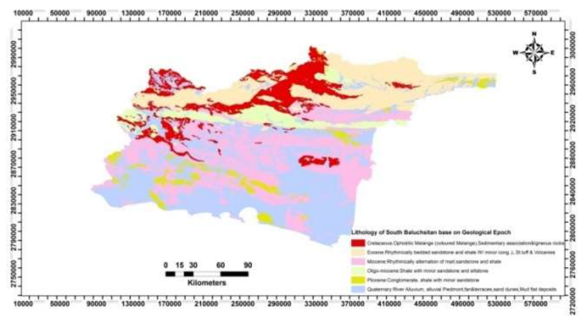

Figure 2: Lithological map of South Baluchistan

METHODOLOGY AND DATA COLLECTION

Lineament analyses was carried out with the help of topographic and geological maps of south Baluchistan on scale 1:100,000 and were supplemented by data from Landsat 8, (LC81570422013146LGN00 and LC81560422013107LGN01). The digital image processing, by using Landsat data, spot images and GIS software, were utilized for preparing the DEM of the study area. It was then geodetically transformed into the Universal Transverse Mercator projection of datum WGS84 in UTM Zones 40R and 41R datum. Based on these models, the lineaments of the region were identified and mapped with regard to their length, number and orientation. The length and number frequency rosette diagrams were subsequently prepared and fitted into a single length-number azimuth frequency diagram.

DISCUSSION AND INTERPRETATION

The satellite imageries were also available for the present study were in bands 1,2,3,4,5,7,8,9,10,11,QA of Landsat 8 on scale 1 : 250,000. The image sharpening was applied to the multi-spectral optical band images for lineament analysis and lithological mapping. This was possible through fusion of panchromatic band with the multispectral bands of LANDSAT 8 image. The fused image is presented as colour composite by assigning bands 2, 5, 7 and 1, 2, 3 to RGB. The fusion of bands 2, 5 and 7 reflected geological features. Lineaments were more visible with fusion of bands 1, 2 and 3 and produced higher frequency number. Therefore, for geomorphic and geological interpretations, the combination of bands 2, 5 and 7, as well as, 1,2 and 3 yielded best inferences. Using the above technique, a lineament map was appropriately prepared. Lineaments were identified on satellite imageries based on the rectilinear or slightly curvilinear disposition of geomorphic features like fault, coastlines, cliffs and river segments. Fault traces and lithological variations were recognised by tonal and textural contrasts and lineaments in visible spectrum. The study area was then subdivided into three sectors, namely;

Sector I: between Ben Tang and Kajoo rivers,
Sector II: between Kajoo and Nikshahr rivers and
Sector III: between Nikshahr river and Kaashi creek.

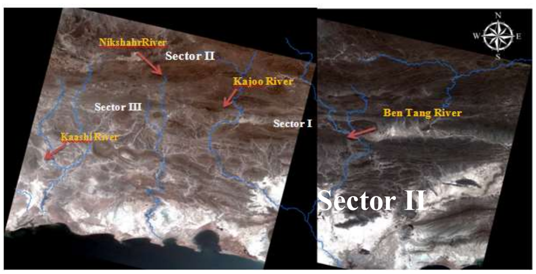

Figure 2: Sattelite imagery (Landsat 8) with three sectors for lineaments analysis with fused bands 1, 2 and 3

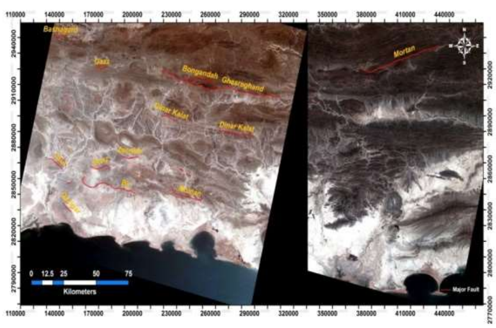

Figure 3: Major lineaments of South Baluchistan on Satellite imagery (Landsat 8) fused bands 1, 2 and 3

Major Lineaments

Within the category 'major lineaments' are included those lineaments which can be traced for tens of kilometers or even more. These were traced along straight or slightly curved segments of major streams, fractures, faults and mountains ranges. The prominent lineaments include

Ghasreghand fault

Ghastreghand fault crosses sectors I and II and extends along east-west direction. In its eastern part, it turns toward NE direction. This fault is responsible for generating earthquakes (Fig. 4). It is a reverse fault with a variable northward dip from 55 to 85 degrees and can be traced for a length of over 200 kms. It also includes its subdivisions such as Bongandah, Gazzand Kahourkan lineaments. This fault crosses over mélange sediments in the eastern part. Faulting was active along this lineament during Pliocene-Miocene period and during Quaternary. This probably indicates right-sliding inverse movement near Ghasreghand city and left-sliding movement to the east of city of Rask. This fault also displaces a series of sinistral northeast trending transverse faults.

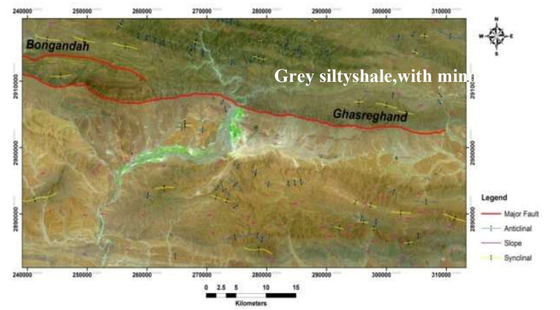

Figure 4: Part of Ghasreghand fault on 2,5 and7 fused bands of Landsat 8

Moman, Bir and Zeerdan faults

Moman lineament (Fig. 3) represents a normal fault trending E-W to NW-SE, having a southwardly dip and shows vertical displacement of about 15 mts. The Bir lineament is also a normal fault which can be traced as an NW-SE trending surface feature for almost 107 kms. The amount of vertical displacement along this fault seems to be more than 50 mts, while to the east of Kahirarea, it shows a displacement of 4 to 7 mts. The Zeerdan fault is another normal fault, traceable for 95 kms and has a southwardly dip of 40^0. Significant characteristic of this fault is its vertical displacement of more than 500 mts. Geologically, Zeerdan lineament represents a very old fault that occurred during the subduction of sedimentary basin or prior to deposition of flysch sediments. This fault was reactivated during late Miocene-Pliocene orogeny and continued up to Quaternary period. It has a E-W trend but in its western part, it assumes a NW-SE trend.

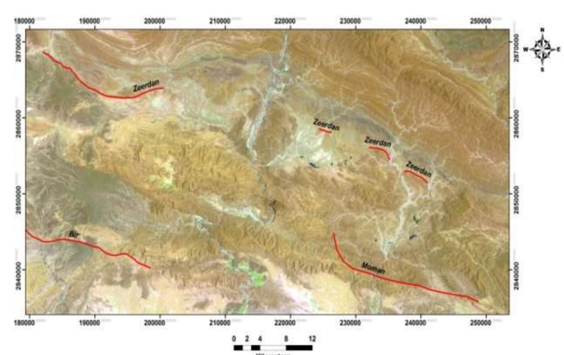

Figure 5: Moman, Bir and Zeerdan faults on 2, 5 and7 fused bands of Landsat 8

LINEAMENT ANALYSES

Sector I

Sector I lies in the eastern part of the study area (Fig. 2) and its lineaments are clustered mainly around two azimuth ranges, namely N 270^{0}-N 279^{0}and N 20^{0}-N 29^{0} as shown in the figure 3 and Table 1. The maxima, in terms of length and number frequency, are 43.51 % and 36.77% respectively.

Table 1: Data for lineaments observed on satellite imageries in Sector 1

Azimuth Range	Length (Km)	Length Frequency	Number	Number Frequency
270-279	1050	43.51	560	36.77
280-289	350	14.50	150	9.85
20-29	748	31.00	310	20.35
30-39	80	3.32	325	21.34
40-49	100	4.14	100	6.57
50-59	50	2.07	53	3.48
60-69	35	1.45	25	1.64
	2413		**1523**	

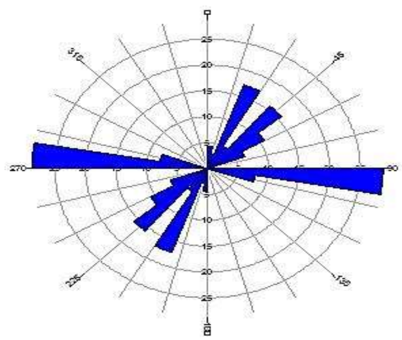

Figure 6: Lineament rosette diagram of sector 1

Sector II

This sector, situated to the west of sector I, has lineaments clustered mainly around two azimuth ranges, namely N 270^{0} - N 279^{0}and N 80^{0}-N 89^{0} (Fig. 4 and Table 2). The maximum azimuth range for length frequency is 26.82% and in terms of number frequency, it is 27.86%.

Table 2: Llineaments on satellite imageries between Kajoo and Nikshahr rivers

Azimuth Range	Length (Km)	Length Frequency	Number	Number Frequency
270-279	281	26.82	250	25.86
280-289	110	10.50	86	8.91
290-299	59	5.60	43	4.45
300-309	176	16.81	34	3.56
320-329	36	3.43	39	4.02
330-339	11	1.05	60	6.24
350-359	84	8.00	86	8.91
0-9	132	12.60	32	3.28
10-19	3	0.27	27	2.77
20-29	27	2.57	18	1.83
50-59	46	4.38	55	5.67
60-69	22	2.06	34	3.56
70-79	18	1.76	30	3.12
80-89	43	4.10	172	17.82
	1048		**967**	

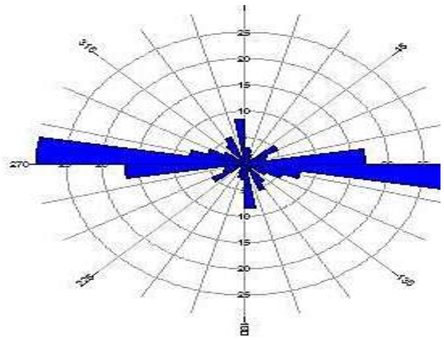

Figure 7: Lineament rosette diagram of sector II

Sector III

This sector is located towards western side of sector II and its lineaments are clustered around azimuth range N 270^0-N 279^0(Fig. 5 and Table 3). The maxima, both in terms of number (30.54%) and length (30.49%) is in the same azimuth range. Some minor lineament clusters are in the azimuth range N 80^0-N 89^0 with the maxima, both in terms of number (18.32%) and length (14.64%), in the same azimuth range.

Table 3: Lineaments on satellite imageries between Nikshahr river and Kaashi creek

Azimuth Range	Length	Length Frequency	Number	Number Frequency
270-279	1101	30.49	536	30.54
280-289	288	7.98	146	8.33
290-299	191	5.28	33	1.87
300-309	413	11.44	39	2.20
310-319	187	5.17	19	1.11
320-329	154	4.27	22	1.23
330-339	228	6.31	161	9.16
340-349	115	3.18	51	2.89
350-359	105	2.90	188	10.70
0-9	22	0.60	9	0.51
10-19	19	0.52	10	0.58
20-29	56	1.56	6	0.33
30-39	46	1.27	25	1.45
40-49	39	1.09	18	1.04
50-59	31	0.86	30	1.72
60-69	51	1.41	41	2.35
70-79	37	1.03	100	5.68
80-89	528	14.64	322	18.32
	3610		**1755**	

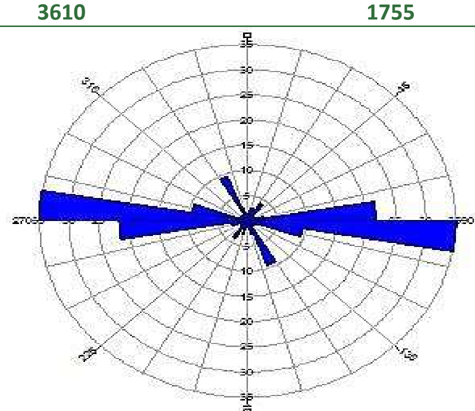

Figure 8: Lineament rose diagram of sector III

Tectonic Interpretations

Limited field checks that were carried out indicate that lineaments essentially represent lines of structural weakness. They represent either zones of shearing or are the reflections in the form of faults and dykes that have emplaced along the lines of tension (Aghanabati, 2004). It may, therefore, be presumed that the lineament fabric essentially reflects the structural fabric of the region. The more important deformational activity took place during the Pliocene orogeny and the lineament fabric suggests that the most effective deformational forces were applied in the middle Pliocene, which caused uplifting of deposited sediments and provided arid environment. During the final stages of this uplifting, deposition of marls and thick conglomerates of Pliocene period occurred which are signatures of the Apline orogenesis. The main structural features in this region are fault zones, which mostly have an east-west trend. There are three main types of faults- reverse, strike-slip and normal faults.

Reverse faults

Reverse Faults, situated on both Upland of Baluchistan (northern part of study area) and Northwest of south Baluchistan, have structurally deformed the rocks of Tertiary to Recent times. The flysch zone, in its lower part consists of clays while the upper part has sandstones and conglomerates (Aghanabati, 2004). These horizons have shown differential resistance towards tectonic stresses. As a result, slope failure appears to be common in the upper consolidated layers. Folding and faulting in upland Baluchistan are usually linear and parallel to each other. Reverse faults belong to early Eocene, with a period of reactivation between Eocene to Pleistocene. They are parallel to the regional structural trends. Ghasregh and Dinarkalat faults are examples of reverse faulting.

Strike-Slip Faults

Strike-Slip Faults also appear in north, northeast and northeast parts of of south Baluchistan. These faults are younger than reverse faults as they cut through them. These faults are usually conjugate and more or less symmetrical along folds axis. These faults mostly occur in sandstones as compared to clay units of flysch formations. Therefore, it is a common believe that the existence of such faults are dependent upon the lithology of rocks. These faults in NE parts tend to cover under the alluvial depositsgradually.

Normal faults

Normal faults are found along the Makran coastal zone where late Tertiary marls of Konarak area have east-west strike and southerly dips. There is no evidence of their occurrence in upland part of south Baluchistan. There is a displacement of 10 mts in these normal faults, especially along marine terraces of Baluchsitan coastline, at Gwadar, Pasandar, Pashat, Konarak and Goksar. These normal faults rarely exhibit strike-slip movements (e.g., at Gwadar and Goksar). Moreover, faults of Pliocene period are of normal type and occur along the Baluchistan coastline. Conversely, those of Pleistocene period, have reverse faulting and are located in the north part of south Baluchistan. Normal faults in Baluchistan coastal belt have developed due to compression and the emergence of faults is due to folding of geological formations with differential resistance to stresses. However, some of the faults are not related to folding (i.e., Zeerdan fault). During depositions of the Flysch facies of Miocene period, intense tectonic movements have taken place affecting the sedimentation within the depositional basin and were responsible for formation of several exotic blocks (e.g., Flysch deposits).

CONCLUSIONS

This study has suggested that the remote sensing data are an effective tool for lineament and structural analysis in the South Baluchistan and provides very useful tools to delineate tectonic features, susceptible to deformational mechanisms, leading to formation of folds, faults and displacement. The main lineaments clustered around azimuth ranges N 270°-N 279°(E-W)while the second lineament strikes clustered around azimuth ranges N20°-N29° (NE-SW). Reverse and strike-slip are conspicuous faults in northern parts while the normal faults are rare and populated in southern area. Based on different tectonic structures in this area, the deformation of rocks occurred because of north-south compressional forces and the subsequent shortening in the same direction is due to folding, faulting and displacement. The intensity and density of faulting in the study area has been controlled by two factors : Geological Time and the litho-structural control. The older units experienced more faulting while there was no appreciable faulting during Pliocene period. These studies also reveal that the formations in the South Baluchistan region experienced normal faulting during Pliocene while during Pleistocene epoch, the reverse faulting had dominated, which indicate differential tectonic control and lithostructural susceptibility.

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