Analysis of Gravel Shapes Along the Khazir River, North of Iraq

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Abstract
This research work deals with the analyses of the shape and size of gravels within the terrace deposit of the Khazir River in the north of Iraq. The degree of gravels’ roundness and flatness indicates that they were transported in wet climate conditions during the deposition of the Bai Hassan Formation of the Pliocene-Pleistocene age. Typical increasing roundness and decreasing flatness along the channel (downstream) refer to the stable flow of the paleo River of Khazir. The higher degree of roundness and flatness of the studied 500 pebbles among the terraces came from the already rounded pebbles of the Bai Hassan Formation, and are not due to the rolling of the sediments of the river that were deposited as terraces along the banks. This case is the only acceptable clue for the origin of the rounded and flattened pebbles that were found in the studied terraces; otherwise, the pebbles wouldn’t be having such roundness and flatness. The aim of this research work is to indicate the roundness and flatness of the gravels within the terrace deposits along the Khazir River.

Keywords: Roundness; Flatness; Terrace deposits; Bai Hassan Formation; Khazir River

1. Introduction

The roundness of clasts represents a characteristic feature which is used mainly to assess the supplying zones of gathered coarse angular rock-mantles that take part in fluvial transport from slopes or tributary rivers (Inman, 1949; Miller et al., 1977; Baba and Komar, 1981), but mainly to reconstruct the transport dynamic and climate condition (Gibbs et al., 1971; Pye, 1994 and Le Roux, 1996) and to discuss the past environmental conditions such as paleo flood depth (Evans, 1991; Howard, 1992; O’Connor, 1993; Sugai, 1993; Plakh, 1998; Grossman, 2001 and Jacobson et al., 2003).

Several studies including both field and laboratory experiments, have shown how different particle shapes of the gavels, exert an influence on bed load transport in coarse-bed rivers, among those studies but not limited to are: Wentworth, 1919; Krumbein, 1942; Unrug, 1957; Sneed, Folk, 1958; Bradley et al., 1972; Komar and Li, 1986; Schmidt and Ergenzinger, 1992; Carling et al., 1992; Schmidt and Gintz, 1995).

Previous studies distribution of gravel shape by size of the particle and lithology of the rock (Krumbein 1941a; Plumley 1948; Van Andel et al., 1954; Stupnicka 1965; Bradley 1970; Bowman 1977; Baumgart - Kotarba 1985; 1989; Dispenbork et al., 1992; Hittingah and Illenberger, 1995).

In Iraq, previous studies of the gravels were mentioned by Jassim (1981) in the Tigris River; a case study between Mosul city and Fatha stretch dealt with large and old alluvial fan. Jassim and Goff (2006) DOI: 10.46717/igj.56.1F.16ms-2023-6-24
described Pleistocene deposits in the Rownduz river (A tributary of the Greater Zab river; NE Iraq), and Sirwan River. They have mentioned that they comprise of sand, silt with varying amounts of gravels, and pebble size of the gravels are generally derived from the Zagros Mountains. Al-Samaray (2005) studied the gravel deposits in the channel of the Tigris River between Baiji and Balad towns (north Baghdad) and the found a change in the shape of the gravels. Kadem et al. (2010) pointed different shapes of the gravels in the Tigris River. Kadem and Hussain (2011) mentioned that the degree of roundness of the gravels is mostly moderate to well rounded in the Tigris River (North Tikrit city).

The literature review presented here shows that our knowledge of the fluvial deposits and roundness and flatness of the gravels in terrace deposits and their transport is still insufficient. The neotectonic may be it is impact on the shape of the gravel within the terrace deposits. The Khazi river (downstream) it is suitable place for this impact. The aim of this research work is to indicate the roundness and flatness of the gravels within the terrace deposits along the Khazir River. The Khazir River rises from the Aqra and Khairy mountains in northern Iraq and then joins the Greater Zab River south of Damir Dagh West Mountain (anticline) with a length of 372 km. The study area is located between Maqlub and Damir Daugh West mountains (Fig.1). In this work, I have divided the Khazir River (downstream) into three courses: the upper course, the middle course and the lower course. This division is attributed to the fact that the river runs through three gorges (Maqlub, Ain Al-Safra and Damir Dagh West mountains).

![Study Area](image)

**Fig.1. Study Area**

### 2. Materials and Methods

ASTER Global Digital Elevation Model (GDEM), version 2 with a 30-m grid data were used in this study. Using ArcGIS software was used to delineate the drainage details of the Khazir River. Arc Hydro tool provided by Arc GIS software was used to demarcate the Khazir River channel. The Geographical Coordinate System (WGS84) have been projected for all used data. The actual land area of the Khazir River was extracted from the DEM map using the basin extraction tool of ArcGIS.

Field survey was carried out to collect 500 samples along the reach of the Khazir River from five locations situated on both banks of the river and represented by equal number of samples. Samples were collected from the terraces using hand shove. Measuring the length and width of the gravels was done...
by Vernier Caliper Plastic Sliding (Fig. 2). The achieved data from each of five studied terrace situations includes 100 gravels and are presented as shape frequency histograms. Analyzing of roundness and flatness of the gravels was done in the Geology Department (Salahideen University, Erbil, Iraq).

The laboratory measurements included particle size measurement ranging from 4 to 6 cm. Roundness of the gravels was measured using curvature template (Diameters are given in millimeters). After the calculation of indices of the roundness and flatness are presented in histograms. According to Cailleux (1942), the roundness and flatness indices are calculated as shown below;

Roundness index = R2 / L * 1000

where R is roundness of gravels and L is length of gravels.

Flatness index = (L+W)/2*T

where L is length, W is width and T is thickness of gravels.

3. Geological Setting

Geological map of the studied basin is shown in Fig. 2. There existing formations in the study area are shown in Table 1 with brief description of the main lithology.

Table 1. Tentative columnar section of the exposed formations in the study area

<table>
<thead>
<tr>
<th>Formation</th>
<th>Age</th>
<th>Thick (m)</th>
<th>General Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bai Hassan</td>
<td>Pliocene –</td>
<td>300 – 500</td>
<td>Thick and coarse conglomerate alternated with thick</td>
</tr>
<tr>
<td></td>
<td>Pleistocene</td>
<td></td>
<td>reddish-brown claystone with rare sandstone</td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td></td>
<td>Grey and coarse sandstone alternated with claystone, and</td>
</tr>
<tr>
<td>Mukdadiya</td>
<td>Miocene –</td>
<td>430 – 500</td>
<td>rare thin beds of fine conglomerate. Some of the sandstone</td>
</tr>
<tr>
<td></td>
<td>Pliocene</td>
<td></td>
<td>beds are pebbly</td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td>300 – 400</td>
<td>Reddish-brown and fine sandstone alternated with</td>
</tr>
<tr>
<td></td>
<td>Miocene</td>
<td></td>
<td>claystone, and siltstone</td>
</tr>
<tr>
<td>Fatha</td>
<td>Middle</td>
<td>120 – 150</td>
<td>Upper Member consist of green marl, limestone, and</td>
</tr>
<tr>
<td></td>
<td>Miocene</td>
<td></td>
<td>gypsum. Lower Member consists of reddish-brown</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>claystone, limestone, and gypsum</td>
</tr>
<tr>
<td>Pila Spi</td>
<td>Eocene</td>
<td>100 – 120</td>
<td>Limestone alternated with dolostone and rare marl</td>
</tr>
<tr>
<td>Gercus</td>
<td>Paleocene-</td>
<td>130 – 150</td>
<td>Reddish-brown claystone with rare sandstone and fine</td>
</tr>
<tr>
<td></td>
<td>Eocene</td>
<td></td>
<td>conglomerate</td>
</tr>
<tr>
<td>Kolosh</td>
<td>Eocene</td>
<td>110 – 180</td>
<td>Limestone, marly limestone, and chert horizons</td>
</tr>
</tbody>
</table>

Lower Khazir River crosses Maqlub, Barda Rash, Ain Al-Safra and Dameer Dagh West anticlines. The change in the river channel are evidenced by the braided throw of low to high sinuosity. In the Maqlub anticline, the reaches upstream and the channel in form of narrow anomalous meandering. In the Ain Al -Safra anticline, the channel widens abruptly due to a fault impact. Then the shape of the stream is straighter with narrow channel in the Dameer Dagh West anticline. Meandering of the river was noticed in both the Maqlub and Ain Al - Safra anticlines.

The Pleistocene river terraces is wind and run-off erosion of and alluvial fans also occurred in Holocene time, providing sediment for fluvial, run-off and Aeolian deposits. From the Pliocene and continued into the Pleistocene folding began in the Foothill Zone during (Jassim and Goff, 2006).
4. Results

The study area was divided into the three courses (Upper, middle and lower) for samples collection and analyzing the gravels roundness and flatness.

4.1. The Upper Course

Three cross section shown in the upper course (Between Maqlub and Ain-Al Safra mountains (Fig.3), the index of roundness of the gravels ranges from 151 to 1000 with maximal frequency in 501-550 classes in the right bank (Fig.4a) and the same classes in the left bank (Fig.5 a). Index of gravel flatness ranges from 3.1 to 17 with a maximal frequency (for most samples) in similar classes between 6.1-7.0 (Fig.4b) and 5.1-6.0 (Fig.5 b).
**Fig. 3.** DEM image showing locations of the sampled sections (a) upper, (b) middle and (c) lower.

**Fig. 4.** (a) Roundness and (b) Flatness of gravels in the right side of the upper course (sample number 1).

**Fig. 5.** (a) Roundness and (b) Flatness of gravels in the left side of the upper course (sample number 2).

In Fig. 6a, maximum classes roundness between 501-550. The degree of roundness does not show unidirectional changes along the river channel. Index of gravel flatness is ranges from 2.1 to 17 with a maximal frequency (for most samples) in similar classes – between 5.1-6.0, 7.1-8.0 and 8.1-9.0 (Fig. 6b).
4.2. The Middle Course

The profile and the location of the middle course are located in the Ain Al- Safra mountain (Fig.3). The index of roundness of the gravels in the middle course ranges from 251 to 951 with maximal frequency between 551-600 classes (Fig.7 a). Index of gravel flatness ranges from 2.1 to 16 with a maximal frequency classes between 5.1- 6.0 (Fig.7 b).

4.3. Lower Course

Fig. 3 shows the profile and the locations of the samples are clear in the lower course of the studied part of the river. The index of roundness of the gravels in the lower course ranges from 151 to 100 with maximal frequency between 701 -750 (Fig.8 a). Index of gravel flatness ranges from 2.1 to 12 with a maximal frequency (for most samples) between 3.1- 4.0 (Fig.8 b).

5. Discussion

Previous studies (Kotarba 1985, 1989; Dispenbork et al., 1992; Hittingah and Illenberger, 1995; Al-Samaray, 2005; Kadem et al., 2010; Kadem and Hussain, 2011) distribution of gravel shape by size of the particle and lithology of the rock.

The presented data were used to assess the relationship between the roundness and flatness of the gravels and distance of the transportation. Results show increasing of gravel roundness (from 450–500
to 700–750 in classes of maximal frequency) and decreasing of their flatness (from 6-7 to 3- 4) downstream along river course. This is attributed to relatively less distance of transport. Increasing of gravel roundness and decreasing of their flatness probably is connected with neo tectonic impact by fold growth of anticline.

Simultaneously, most frequency of roundness indices fall between 450- 750 which is inconsistent with the present– day fluvial transport in an intermittent river in semi-arid climate. These values are rather characteristic for moderate climate (Demir et al., 2007; Dogan, 2010).

Contemporary channel gravels are derived mainly from erosion of older (Pleistocene) terrace deposits with admixture of slope material. Location of investigation sector of channel in syncline is favorable for meandering and marginal erosion. That original of channel gravels is confirmed by histograms of roundness and flatness, which have not distinct marked maximum and comprise a wide range of classes. It means that the gravels were derived from various sedimentological sources (Sissakian and Al-Jiburi, 2012).

The catchment area of the Khazir River is within Aqra Mountain (Anticline) where rocks of Lower Cretaceous (Qamchuqa Formation) are exposed represented. The majority of the exposed rocks in Aqra anticline are of carbonate type; however, along the limbs clastic rocks are exposed (Sissakian and Al-Jiburi, 2012). When Khazir river flows out of the anticlines, among the exposed formations (the Bai Hassan Formation), which consists of alternation of conglomerate and claystone with rare sandstone (Sissakian and Al-Jiburi, 2012).

The conglomerate beds consist of gravels of different sizes that range between few millimeters to 25 cm; exceptionally may reach 35 cm, and even more, the size increases in the middle part of the formation, then decreases again in the upper parts. The pebbles are mainly of silicate and carbonate, with subordinate igneous and metamorphic rocks. Among the silicates are white quartz, chert, flint, silicified sandstone. The thickness of the individual bed ranges from 5 m; in the lower course to 30 m; in the upper course. The pebbles are sub rounded to well rounded, varicolored, elongated, semispherical, rode and disc shaped, cemented by calcareous and sandy materials, locally gypsiferous. Occasionally, grey, coarse grained sandstone lenses and/ or beds (up to 4 m); some are pebbly; may occur within the individual bed (Sissakian and Al-Jiburi, 2012).

Among the terraces of Khazir River, white quartz pebbles, carbonates and rare igneous and metamorphic rocks occur. Since there are no such rocks exposed in the catchment area of the river; therefore, these pebbles in the terraces are certainly derived from the exposures of the Bai Hassan Formation which are widely exposed along the river course (Sissakian and Al-Jiburi, 2012). Accordingly, the roundness and flatness (Pliocene-Pleistocene) of the studied pebbles among the terraces came from the already rounded pebbles of the Bai Hassan Formation, and are not due to the rolling of the sediments of the river that were deposited as terraces along the banks.

This case is the only acceptable clue for the origin of the rounded and flattened pebbles that were found in the studied terraces; otherwise, the pebbles wouldn’t be having such roundness and flatness.

6. Conclusions

The granulometric feature of the channel does not reflect the present-day conditions of fluvial transport. The degree of gravels roundness and flatness points to their fluvial transport in wet climate conditions. Typical increasing of roundness and decreasing of flatness along the channel can point to stable flow of Khazir River during the Pliocene - Pleistocene. Re-deposition character of present-day channel gravels proves that the marginal erosion as the contemporary main fluvial process in periodical river was dominant.
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