Tectonophysics 608 (2013) 914–928

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Analyzing the drainage system anomaly of Zagros basins: Implications for active tectonics

Shahram Bahrami *

Department of Physical Geography, Faculty of Geography and Environmental Science, Hakim Sabzevari University, Sabzevar, Iran

A R T I C L E I N F O

Article history:
Received 1 March 2013
Received in revised form 22 June 2013
Accepted 20 July 2013
Available online 31 July 2013

Keywords:
Hierarchical anomaly number
Basin shape
Hinge spacing
Zagros
Tectonic

A B S T R A C T

Morphometric analysis of hierarchical arrangement of drainage networks allows to evaluate the effects of external controls especially tectonics on basin development. In this study, a quantitative method for calculation of stream's hierarchical anomaly number is introduced. Morphometric parameters such as hierarchal anomaly index (Δa), percent of asymmetry factor (PAF), basin Shape (Bs), basin length to mean width ratio (Bl/Bmw), stream's bifurcation ratio (Rb), bifurcation index (R), drainage density (Dd), drainage frequency (Df) and anticline's hinge spacing (Hs) of 15 basins in Zagros Mountains were examined. Results show that the strong correlations exist between pairs Δa–PAF ($r = 0.844$), Δa–Bs ($r = 0.732$), Δa–Bl/Bmw ($r = 0.775$), Δa–R ($r = 0.517$), PAF–Bl/Bmw ($r = 0.519$), Bs–R ($r = 0.659$), Bl/Bmw–R ($r = 0.703$), Hs–Δa ($r = -0.708$), Hs–PAF ($r = -0.529$) and Hs–Bs ($r = -0.516$). The variations in trend of anticlines control the shape of basins so that where anticlines hinges become closer to each other in the downstream direction, basin become narrower downward and hence the Δa increases. The more uplifted northeastern anticlines cause the trunk river of the basins to migrate toward the younger anticlines in southwest and hence Δa increases because the trunk river receives a lot of first order streams. Data reveal that the rate of Δa is higher in elongated synclinal basins. Due to the decrease in the intensity of deformation from northeast toward southwest of Zagros, the hinge spacing of anticlines increases southwestwards. Data reveal that the variation in hinge spacing of anticlines strongly controls the basin's shape and tilting as well as the hierarchical anomaly of drainage system. Since the elongation and tilting of basins are associated with the variations in rates of folding, uplift and hinge spacing of anticlines, it can be concluded that the hierarchical anomaly of drainages in studied basins is controlled by the intensity of Zagros tectonic activities.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Rivers and their tributaries are the key features of a drainage basin. The quantitative study of drainage system was initiated by Horton (1945) followed by Strahler (1952), in which they introduced the concept of stream ordering. Morphometric characteristics of drainage system of many basins and sub basins in different parts of the globe have been studied widely (Abrahams, 1984; Altin and Altin, 2011; Horton, 1945; Krishnamurthy et al., 1996; Kumar et al., 2000; Leopold and Miller, 1956; Reddy et al., 2004; Shreve, 1966; Strahler, 1952, 1957).

The development of landscapes in tectonically active areas results from a complex integration of the effects of vertical and horizontal motions of crustal rocks and erosional processes (Burbank and Anderson, 2001). In tectonically active regions especially in folded mountains, qualitative and quantitative analyses of drainage systems are useful to evaluate the impact of tectonic activity on geomorphic processes and landscape development (Burbank and Anderson, 2001; Delcaillau et al., 1998; Delcaillau et al., 2006; Jackson et al., 1998; Ramsey et al., 2008; Sung and Chen, 2004).

Morphometric parameters of drainage system such as drainage density and frequency, bifurcation ratio, confluence angle have been widely analyzed in relation to active tectonics (Deffontaines and Chorowicz, 1991; Devi et al., 2011; Jamieson et al., 2004; Simoni et al., 2003; Talling and Sowter, 1999; Zhang et al., 2006).

The analysis of drainage pattern and anomaly also has the potential to record evidence of active tectonic and fold growth (Deffontaines et al., 1992; Delcaillau et al., 2006; Ramasamy et al., 2011; Simoni et al., 2003).

Most recently, some researchers have introduced valuable attributes of drainage systems and their relevance to active tectonics. For example, Ramsey et al. (2008) revealed that the development of distinctive asymmetric forked tributary patterns and the curve of the tributary headwaters into a direction parallel to the fold crest are geomorphic evidence of lateral fold growth in Zagros, Iran.

Bretis et al. (2011) demonstrated that the development of asymmetric forked drainage network and curved wind gaps are powerful geomorphic indicators showing lateral propagation of Bana Bawi, Permam and Safeen anticlines in NE Iraq.

* Tel.: +98 5714003231; fax: +98 5714003270.
E-mail addresses: s.bahrami@hsu.ac.ir, shahram_bahrami2003@yahoo.com.

0040-1951/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.tecto.2013.07.026

Ramasamy et al. (2011) mapped some drainage anomalies like deflected drainages, eyed drainages and compressed meanders of South India and, thereby, detected a series of faults with well-defined morphology. Based on the interpretation of drainage anomalies and the related lineaments/faults, they have provided definite information for the post collision tectonics, which are currently active, and hence bear greater significance in the context of fast relapsing seismicities in the area.

Walker and Allen (2012) revealed that right-lateral movement of the Kuh Banan Fault in eastern Iran has resulted in the formation of numerous river offsets. They noted that small and highly variable drainage spacing ratios of the Kuh Banan fault is due to structural complexity and resultant topographic variation deflecting rivers and affecting drainage basin shapes on smaller scales.

Based on the qualitative and quantitative geomorphic analyses, Giaconia et al. (2012) showed that the reverse faults of Cabrera, SE Spain, have produced knickpoints, stream deflections, complex basin hypsometric curves, high SLk (normalized stream-length gradient index) anomalies and highly eroded basins in their proximity. They also revealed that the drainage network shows an S-shaped pattern reflecting progressive anticlockwise rotation related to the sinistral Palomares fault zone.

Based on parameters of the hierarchy of the drainage network such as bifurcation ratio (Rb) and bifurcation index (R), Raj (2012) noted that the eastward tilting of the drainage systems in the NE Gujarat (India) and the movement along various faults in the region has resulted in the poor organization of some hydrographic networks.

Although drainage system characteristics and tectonic interactions have been widely studied, little work is available on the hierarchical arrangement of drainage systems. The hierarchical organization of drainage networks has first been analyzed by means of bifurcation ratio (Horton, 1945). Subsequently, in order to better define the organization of drainage system, Avena et al. (1967) introduced the direct bifurcation ratio (Rbd), bifurcation index (R), hierarchical anomaly number (Ha), hierarchical anomaly index (Δa) and hierarchical anomaly density. Some researchers have evaluated the application of hierarchical anomaly number (Ha) and index (Δa) to detect tectonic activity (Guarnieri and Pirrotta, 2008) and to estimate the suspended sediment yield of basins (Ciccacci et al., 1986; Della Seta et al., 2009; Della et al., 2007; Gioia et al., 2011; Grauso et al., 2008).

Guarnieri and Pirrotta's (2008) studies on the Ha and Δa parameters showed the limited organization of the drainage system of the Curcuraci and Papardo fiumare basin (in the Sicilian side of the Messina Strait, NE Sicily) due to active tectonics.

Tectonically active and young Zagros Folded belt (Berberian, 1995) is composed of NW–SE trending and whaleback anticlines and synclines with large variation of fold dimensions. Although some researchers (Alipoor et al., 2011, 2012; Bahrami, 2012; Bretis et al., 2011; Piraste et al., 2011; Ramsey et al., 2008) have analyzed the relations between active tectonics and drainage systems, the quantitative evaluation of hierarchical arrangement of drainage systems in Zagros in currently lacking.

The aim of this research is to introduce a quantitative method for the calculation of hierarchical anomaly number in every drainage junction (path) and thereby in the whole catchment. In this study, 15 catchments with different shapes and areas in the Folded Zagros were selected, then hierarchical anomaly index (Δa) of streams were calculated, and results were correlated with other morphometric indexes of catchments.

2. Study area

Studied basins in SW Iran (Fig. 1) lie within the Zagros Simply fold belt. A total of 15 basins were selected in 3 provinces. Basins 1 to 6 are located in Kermanshah, basins 7, 8, 9, 11 and 12 are parts of Ilam and basins 10, 13, 14 and 15 are located in Lorestan province.

Structurally, the studied basins are part of the Zagros belt in southwest Iran. Zagros belt as a part of Arabia–Eurasia collision zone extends for 1500 km from the Taurus Mountains in southeast Turkey through southwest Iran, and terminates near the Hormuz Strait at the mouth of the Persian Gulf. Geomorphologically, Zagros belt is divided into two adjacent belts: the High Zagros Belt and the Zagros Simply Folded Belt (ZSFB), separated by the High Zagros Fault (Berberian and King, 1981; Falcon, 1974). The ZSFB is bounded to the northeast by the Zagros Main Thrust and separated by this fault from the Sanandaj–Sirjan metamorphic belt (Emami, 2008).

The ZSFB results from the closure of the Neo-Tethys Ocean between the Arabia margin and the Eurasia continent (Stocklin, 1968).

Since the onset of continent–continent collision between the Arabian and Iranian plates in the Tertiary, a major pulse of compressional deformation has been propagating southwestward, away from the collision zone and towards the foreland (Sepehr et al., 2006). The GPS measurements indicate that shortening is not distributed homogeneously either along or across the Zagros belt (Hessami et al., 2006).

Falcon (1974) inferred that the regional uplift represented by 'geo-flexure' implied that the Zagros had risen at a minimum rate of 1 mm/yr since the early Pliocene.

According to Tatar et al. (2002), present-day NE–SW shortening across the central part of the Simple Folded Zone of Zagros is c. 10 mm/yr. Blanc et al. (2003) suggested that, if the Simple Folded Zone deformation has taken place since c. 5 Ma, this corresponds to a shortening rate of c. 10 mm/yr which is a substantial part of the present Arabia–Eurasia convergence rate. Based on a few stations located in the Zagros, Nilforoushan et al. (2003) and Vernant et al. (2004) showed that the rate of shortening increases from 4 ± 2 mm/yr in the NW to 9 ± 2 mm/yr in the SE Zagros. Generally, rates of deformation and shortening diminish southwestwards in the Zagros fold–thrust belt (Hessami et al., 2006; Lawa et al., 2013).

The stratigraphy of the NW Zagros is a 10–12 km-thick section of lower Cambrian through Pliocene strata (Falcon, 1969). The stratigraphic column of Zagros is divided into the five structural divisions (Colman-Sadd, 1978); the Basement group, the Lower Mobile group, the Competent group, the Upper Mobile group and the Incompetent group (for stratigraphic details of Zagros, see Colman-Sadd, 1978; Alavi, 2004).

The lithological units outcropping in the studied basins are Sarvak (Limestone and shale), Gurpi (marl and marly limestone), Pabdeh (calcareous shale, marl and mudstone), Amiran (conglomerate, sandstone, siltstone and shale), Taleh Zang (limestone with intercalations of shale and argillaceous limestone), Kashkan (siltstone, sandstone and conglomerate), Asmari (limestone and dolomitic limestone), Gachsaran (marl and limestone with intercalations of gypsum and anhydrite), Mishan (marl and limestone), Agha jari (marl and sandstone), Bakhtiari (conglomerate) and Quaternary Alluviums. The area percent of lithological units for all basins is given in Table 1.

The ZSFB is composed of long, asymmetrical, whaleback or box-shaped anticlines which generally trend NW–SE. According to Colman-Sadd (1978), most folds in the simply folded belt of Zagros are asymmetric and, with a few exceptions, the steepest limbs of the anticlines are on the southwestern limbs. Narrow and V-shaped valleys are characteristics of the steep slopes of anticlines (Fig. 2e). Since the majority of anticlines around studied basins are composed of carbonate rocks (i.e. Asmari unit), karstic features are dominant landforms of the study area (Fig. 2a). The most typical karstic features of basins are karrens, dolines, and caves.

The area, perimeter and topographic characteristics of basins are given in Table 2. The lowest value of area is related to basin 11 (10.75 km^2) and the highest value is associated with basin 4 (285 km^2). The maximum elevation is related to basin 8 (2620 m a.s.l) and the minimum elevation is associated with basin 12 (510 m). The mean elevation is higher in basins 5, 6 and 9 than other basins. The value of mean slope is higher in basins 12, 13 and 14 (respectively 40.56%, 37.93% and 31.7%) than other ones (Table 2).

Hydrologically, basins 1 to 4 are upstream sub-basins of Alvand River that flows to Iraq near the town of Qasre-Shirin. Basins 5, 6, 8 and 10 to

Download English Version:

https://daneshyari.com/en/article/6434018

Download Persian Version:

https://daneshyari.com/article/6434018

Daneshyari.com