



TAPHONOMY OF SOME VERTEBRATE FOSSILS FROM HEMRIN ANTICLINE, MIDDLE IRAQ

Aqeel A. Al-Zubaidi^{*}, Yasamin K. Ibrahim¹ and Hassan K. Jasim²

^{*}Iraq Natural History Research Center and Museum, University of Baghdad

^{1&2}Department of Geology, College of Science, University of Baghdad

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ABSTRACT

The study area is located near Injana area; about 140 Km north of Baghdad City, middle Iraq. The Late Miocene – Pliocene site of the Mukdadiya Formation which is exposed in the northeastern limb of Hemrin South Anticline is a good example for the vertebrate fossil bones. The fossil bones can be studied by multidisciplinary sciences; tectonics, sedimentology, vertebrate fossils taxonomy and volcanic activities to understand the taphonomic processes of the involved fossil assemblages. The Alpine Orogeny in the Late Miocene increased the uplifting, folding and shortening of the Zagros Thrust Fold Belt and subsidence of the Zagros Foreland Basin in middle Iraq. Large fluvial systems, especially alluvial fans have been flowing from the northeast to the southwest in relatively humid climates. The current study concluded the following: The appearance of 21 species in the site refers to the humid and more luxurious environment. Availability of water and sediments (sand, mud, and clay) near fluvial sub environments enriched the diversity of plant that helped a different kind of amphibians such as crocodiles and turtles to living and breeding. The plant diversity provided the food for herbivores such as deer, giraffes, horses, mastodons, and later for the predators and carnivores. The presence of tuff stone, glass shards, pyroclastic crystals, tuffaceous sandstone, tuffaceous mudstone and tuffaceous claystone refer to volcanic activities and caused the suffocation and mass mortality of animals during the Late Miocene – Pliocene. Soft parts of dead animals were decay, while the bones transported by fluvial channel during heavy rain and mixed with the channel bed loads. They might be deposited and reworked by many cycles of deposition and finally, the redeposit within channel lag deposits in the lower part of point bars of the fluvial environment.

Keywords: Taphonomy; Sedimentation; Vertebrate fossils; Volcanic; Pliocene; Iraq

INTRODUCTION

Taphonomy is the science that study embedding law of animal and plant remains (Valli, 2005). Vertebrate fossils were studied by many authors in Jabal Zaltan, in Libya (Sanders, 2008); in Pakistan, rich vertebrate fossil successions, within Siwalik Group (Nanda, 2002 and 2008; Khan *et al.*, 2009 and 2010; Aftab *et al.*, 2016) and in South Africa (Hendey, 1981; Hendey, 1982). Many important sites of vertebrate remain have been studied in Iraqi adjacent countries, such as in Turkey, at Akkasdagi (L. Miocene) (Valli, 2005) and in Maragheh Formation at northwestern Iran (Berner *et al.*, 1996; Berner *et al.*, 2001). Some vertebrate remains were discovered in Iraq (Piveteau, 1935; Al-Naqib, 1959; Bellen *et al.*, 1959; Thomas *et al.*, 1981). At last decades many authors used specific terminology, to show the effect of taphonomic processes on the distribution of vertebrate fossils' records and integration of concept and data (Lyman, 1987). In addition to show the distribution and preservation of vertebrate fossils and their relation to sedimentology and paleoclimate in Ischigualasto Formation, in northwestern Argentina (Colombi *et al.*, 2012). The study of taphonomy and sedimentology is to determine the time duration between the death of whales and burial by diatomaceous sediments of Pisco Formation, in Peru (Esperante *et al.*, 2003). Many vertebrate fossil remains in Iraq come from the Injana Formation (Late Miocene) and the Mukdadiya Formation (Late Miocene – Pliocene), (Al-Zubaidi and Jane, 2015). The main important work is done in Iraq by a cooperation of Iraqi Geological Survey (GEOSURV) and Centro Studi Ricerche Ligabue in Venice, Italy (Thomas *et al.*, 1981). Vertebrate fossils' studies in Iraq still rather few as compared to that of other countries in the region like Iran and Turkey. This study focused on the application of taphonomy, for the first time in Iraq, on the vertebrate fossils of Mukdadiya Formation (Late Miocene – Pliocene) which were discovered by Thomas *et al.*, (1981) in Hemrin South Anticline and using collected data from the style of preservation, tectonic and sedimentation to reconstruct the paleoenvironment and explain the factors which have caused the vertebrates animals mortality.

Location: The study area is located near Injana region, about 140 Km north Baghdad City, middle Iraq (Fig. 1). The vertebrate fossils are the presence in the outcrops of the northern part of the northeastern limb of Hemrin South Anticline, within the clastic rock of the Mukdadiya Formation (Late Miocene – Pliocene).

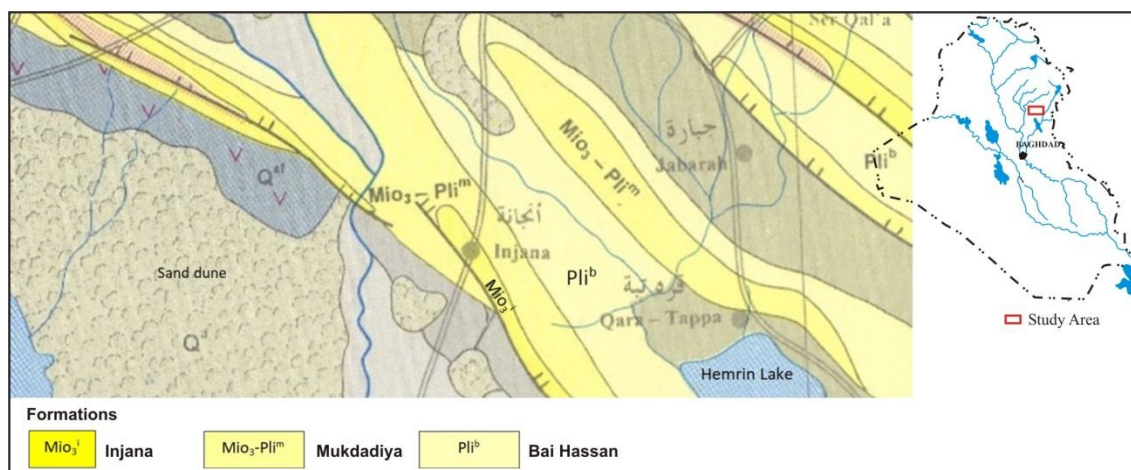


Fig. 1: Location and geological maps of the study area (GEOSURV Iraq, 2000)

MATERIALS AND METHODS

Data collection of current study depends upon field surveys in the study area near Injana Region and published papers which deal with the vertebrate fossils of the Mukdadiya Formation (Late Miocene – Pliocene) in Iraq, which do not apply taphonomy. The current study focused on local and regional tectonics, sedimentology of rock units including bone fossil assemblages, vertebrate fossil bone photographs of Thomas *et al.* (1981), and the impact of volcanic activities. The above-mentioned data are compared with many recent studies to provide basic information and interpretation to infer the taphonomy of the Mukdadiya Formation (Late Miocene – Pliocene).

GEOLOGIC SETTING

The collision of the Arabian (Neo-Tethyan terrains) and Iranian (Sanandaj – Sirjan Zone) Plates during L. Miocene – Pliocene caused folding in the Low Folded Zone, in addition to the end of marine sediments and beginning of the clastic continental sediments. The clastic continental sediments, which include Injana and Mukdadiya Formations, had been increased in size continuously and cover wide areas. Involved sediments were folded during the last phase of Alpine Orogeny (Sissakian and Al-Jibouri, 2012). The Injana and Mukdadiya basin (Late Miocene – Pliocene) is a part of the subsiding Zagros Foreland Basin, which is related to the Zagros Thrust – Fold Belt and the Arabian Plate (Jassim and Goff, 2006). Vertebrate fossils occur in the Injana Formation (Late Miocene), (James and Wynd, 1965; Al-Hashimi and Yaqoub, 1974) and in the Mukdadiya Formation (Late Miocene – Pliocene), (Piveteau, 1935; Astre, 1936; Al-Naqib, 1959; Bellen *et al.*, 1959; Thomas *et al.*, 1981; Al-Zubaidi and

Jane, 2015). The records of the Iraq Natural History Research Center and Museum-University of Baghdad and the author's field survey refer to the presence of some broken fragments of vertebrate fossil bones in the Mukdadiyah Formation near Al-Mukdadiya Town. The fossiliferous layer, within Mukdadiya Formation, is extended more than 30 Km, it is located along the northeastern limb of the Hemrin South Anticline. All fossils were found in a sandy conglomerate which consists of light grey sands with many heavy minerals (Slavic and Al-Hashimi, 1977). The important exposed formations in the study area are Mukdadiya Formation, which includes the studied vertebrate fossils, in addition to the Injana Formation. The formations are describing below.

Injana Formation: The type section of the Injana Formation (Late Miocene) is located in Injana area at Hemrin South Anticline, about 120 Km northeast of Baghdad City, on the main road of Baghdad – Kirkuk, (Longitude 44° 38' 10" E, Latitude 34° 32' 00" N), (Jassim *et al.*, 1984). The Injana Formation was first described by Busk and Mayo in 1918 in Iran (Bellen *et al.*, 1959). It is comprised varicolored mudstone, siltstone and sandstone, with rare thin beds of freshwater limestone and some gypsum horizons, in the lowermost part (Jassim *et al.*, 1984 and Al-Rawi *et al.*, 1992) which is deposited from a fluvial system (Al-Zubaidi, 2004). It has the same lithologic units, in the other exposure areas, of cyclic repetition of mudstone, siltstone and sandstone (Sissakian and Al-Jibouri, 2012). It is underlain by the Fatha Formation when a thick anhydrite rock bed unit appears and overlain by Mukdadiya Formation when the first pebbly sandstone appears (Bellen *et al.*, 1959; Buday, 1980; Jassim *et al.*, 1984 and Al-Rawi *et al.*, 1992). The thickness is variable, but it is 620 meters at the type section (Jassim *et al.*, 1984 and Al-Rawi *et al.*, 1992) and the maximum thickness reaches to 900 meters at the Low Folded zone near Kirkuk City (Jassim *et al.*, 1984). The Injana (Upper Fars) Formation is exposed at central and NE Iraq (Fig. 2) and it is called Mishan Formation in Iran, Siirt Series in Turkey and Upper Fars in Saudi Arabia (Buday, 1980).

Mukdadiya Formation: The type section of the Mukdadiya Formation (Late Miocene – Pliocene) is located on the main road between Mukdadiya Town and Saadiya Town, on the northeastern of Hemrin South Anticline. The coordination of type section is: Longitude 45° 01' 50" E and Latitude 34° 02' 10" N (Jassim *et al.*, 1984). The name, of Mukdadiya and Bai Hassan were used by Jassim *et al.* (1984) and firstly described in

Iran as a Lower and Upper Bakhtiari Formations by Busk and Mayo in 1918 (Bellen *et al.*, 1959). The Mukdadiya Formation (Late Miocene – Pliocene) comprises of about 2000 m of interbedding sandstone and mudstone of fining upward cycles. The sandstone is characterized by cross-bedding, channel lag deposits and mud balls; which were deposited in rapidly in a subsided basin (Jassim and Goff, 2006) from the fluvial environment (Al-Shammari, 2009). The Mukdadiya Formation is overlain by Bai Hassan (Upper Bakhtiari) Formation and underlain by Injana (Upper Fars) Formation and exposed at central and NE Iraq (Fig. 2). It is called Agha Jari Formation in Iran and also extended to north and northeast of Syria, and south of Turkey (Jassim and Goff, 2006).

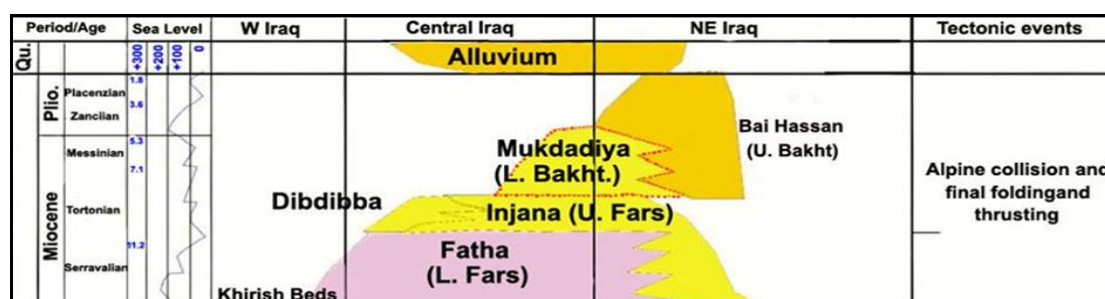


Fig. 2: Occurrence, distribution and the tectonic event of the Injana (Late Miocene) and the Mukdadiya Formation in Iraq (Jassim and Goff, 2006)

RESULTS

The main used methods for taphonomic studies include, the collection of all vertebrate fossil remains more than 2 cm, description of rock exposures, photography of each found fossils as it is in the field, facies analysis for sediments to reconstruct the paleoenvironment (Fernández-Jalvo, and Andrews, 2016). Taphonomic methods of the current study depend on Tectonic and sedimentation, vertebrate fossils, and volcanic activities of Mukdadiya Formation (Late Miocene – Pliocene), which are described below.

Tectonic and sedimentation: In the Middle Miocene – early Late Miocene time renewed compression occurred along the Tethyan (Zagros) suture zone. The accretionary prism formed of relatively soft sediment was uplifted and rapidly eroded with the transport of sand, fine silt and mud into a new foreland basin in NE Iraq and SW Iran (Fatha and Injana formations). In the uppermost Late Miocene time further strong compression occurred, which propagated into the Mid Miocene foreland basin

resulting in the growth of the large Zagros Anticlines. A rapidly sinking foredeep basin formed in N and NE Iraq flanked by a thrust belt. The folding during the Alpine Orogeny was increased in that time and increased of the eruption and volcanic ash (Jassim and Goff, 2006). The volcanic ash is distributed in wide areas and deposited within the rock bed units of the Mukdadiya Formation (Late Miocene – Pliocene), particularly in the areas of Qara Tappa and Zerluk near the Injana area in middle Iraq. Thickness of the volcanic ash bed is: 3, 1 – 2.5 and 0.3 – 0.5 meters of facies (A), (B) and (C) respectively (Al-Hassan and Al-Zaidy, 2012), with lenticular shape within rock bed units of fluvial environment of deposition (Buday and Jassim, 1987), which led to animal's mortality (Numan, 1997). Large rivers transported their clastic sediments to the vertebrate fossil remains to the basin of the Injana Formation. In Late Miocene-Pliocene time further compression led to increase rivers flow, velocity and energy of transportation, from the northeast to southwest (Kukal and Saadallah, 1970) and procreation of huge alluvial fans into the Foreland Basin within the Mukdadiya Formation (Late Miocene – Pliocene).

Vertebrate fossils: Mortality of most animals occasion for vertebrate animals result from attrition or old aging; or may be attacked by carnivorous; or mass mortality resulted from natural catastrophic such as suffocation by poisonous vapor and gases which are erupted from volcanoes (Valli, 2005). Previous research in Iraq indicated that most vertebrate fossils (bones and teeth) come from the Injana Formation (Late Miocene) and Mukdadiya Formation (Late Miocene – Pliocene) (Thomas *et al.*, 1981; Al-Zubaidi and Jan, 2015). No systematic studies for these fossils have been done in Iraq except for the research by Thomas *et al.* (1981), they identified 21 species of vertebrate fossils collected from a sandy conglomerate within a distance of 30 Km. The fossils accumulation show difference in age, juveniles mixed with adult and old animals (Plate 1) because the sample have varying degree of tooth wear stages on the occlusal surfaces to both upper and lower premolars and molars teeth, for example: *Samotherium* cf. *boissieri*: left M2 is much worn than *Palaeotragus coelophrys*: left mandible with P3 and M1 indicated older than the other and can estimate the age during the death by the relationship between the surface wear and age and related that with natural population and dependent on the diet and feeding habits (Morris, 1972; Grant, 1982). The existence of these fossils in different ages mixed with each other indicates the

occurrence of a natural external effect led to the mass mortality of the population during Pliocene.



Plate 1: Occlusal views for *Samotherium cf. boissieri*. (A) worn left M2. Palaeotragus coelophrys; (B) left M1; (C) left M3. (modified after Thomas *et al.*, 1981)

Volcanic activities: The rock bed unit of Mukdadiya Formation (Late Miocene – Pliocene) contains volcanic ash bed sediments, up to 8 meters exposed near Qara Tappa and Zerluk, which are not far away from the study area. They have lenticular layers and deposited from aquatic, fluvial or lake, environment of deposition (Buday and Jassim, 1987). Volcanic ash sediments of the Mukdadiya Formation have been subdivided into three main facies, which were subdivided into eight subfacies (Al-Hassan and Al-Zaidi, 2012) (Table 1). Facies (A), Primary pyroclastic facies: It is deposited directly from air to the aquatic, fluvial or Lake environment of deposition without mixing with terrigenous materials, its thickness is about 3 meters, includes coarse grains 0.45 – 0.063 mm and fine grains 0.063 – 0.005 mm, composed of glass shards and pyroclastic crystals. Facies (B), secondary pyroclastic facies (or Tuffaceous rocks): It is deposited from volcanic ash and reworked by many cycles of transportation and

deposition, which caused mixing of pyroclastic sediments and terrigenous materials. The thickness of facies (B) ranged from 1 – 2.5 meters and contains sandy tuff stones, tuffaceous mudstone and tuffaceous claystone. The appearance of Facies (A) and (B) refer to volcanic activities during deposition of the rocks of the Mukdadiya Formation (Late Miocene – Pliocene). Volcanic activities accompanied by many vapors and gases eruption such as HCl, HS, SO₂, and CO₂, which may cause difficulty in breathing and suffocation (McGeary and Plummer, 1988) in addition to the death and extinction of organisms (Numan, 1997).

Table 1: Volcanic ash sediments lithofacies of Mukdadiya Formation (Late Miocene – Pliocene) after (Al-Hassan and Al-Zaidi, 2012)

lithofacies	Facies	Thickness (m)	Sub facies	description
primary Pyroclastic Facies: (Tuffstone), composed of: glass shards (vitric 85%) and pyrogenic minerals (15%).	A	3	A ¹	Coarse-Grained Tuffstone
			A ²	Fine-Grained Tuffstone
secondary Pyroclastic Facies; (Reworked sediments): composed of: glass shards (vitric 65%) and (pyrogenic minerals <10%).	B	1 – 2.5	B ¹	Sandy tuff stone
			B ²	muddy tuff stone
			B ³	clayey tuff stone
secondary Pyroclastic Facies; (Reworked sediments): composed of, detrital clasts (>85%) and pyrogenic material (vitric pyrogenic minerals <15%).	C	0.3 – 0.5	C ¹	tuffaceous sandstone
			C ²	tuffaceous mudstone
			C ³	tuffaceous claystone

DISCUSSION

The collision of the Arabian and Iranian plates in the Late Cretaceous Period caused the growth of Zagros Fold-Thrust Belt, and increase in uplifting, folding and shortening of these areas and surroundings. The regression of the Zagros Foreland Basin and the area passed in three stages time wise, which has a great influenced on the Living animals in this area:

Time 1: During the Late Miocene, the large rivers formed running from the highlands, Zagros Fold Thrust Belt, towards the low land of the foreland. River environments include many subenvironments like river channels, over banks, flood plains, swamps and oxbow lakes. Involved environments were characterized by the abundance of water, sand, silt and clay sediments that help the growth of diverse natural plants. These areas have become a good breeding ground for herbivorous animals such as deer (*Prostrepsiceros houtumschindleri*, *Gazella cf. deperdita*), giraffes (*Palaeotragus*

coelophrys, *Samotherium* cf. *boissieri*, cf. *Bohlinia attica*), horses (*Hipparion* cf. *primigenium*, *Hipparion mediterraneum*), rhinoceros (*Brachypotherium* cf. *perimense*), and elephants (*Choerolophodon pentelici*) as well as amphibians and turtles (*Trionyx* s. l., *Geochelone* sp.), and crocodiles (*Gavialls* sp.). Later on, predators and carnivores appeared such as *Machairodus* sp.

Time 2: During the late Miocene – Pliocene, the Alpine Orogeny was climaxed, in addition to volcanic activity and eruption of lava, ashes and volcanic dust, caused the distribution of hot rocks, may be reached 700 °C and the emission of hot poisonous vapors and gases (HCl, HS, SO₂, and CO₂). Distribution of ash and volcanic dust in the atmosphere on large distances caused difficulty in breathing and suffocation of many animals that lived in the concerned region. The hard remains were deposited within rocks of the Mukdadiya Formation (Late Miocene – Pliocene). This led to a catastrophic event in mass mortality of the animals due to volcanic activity. The accumulation of tooth fossils, of different ages, include juveniles, adult and old animals, in addition to the bone fossils of herbivorous and carnivorous which appeared within the rocks of the Mukdadiya Formation refers to mass mortality of animals during Late Miocene – Pliocene Time.

Time 3: Volcanic activities at Pliocene caused mass mortality of the vertebrate animals and decay of the soft parts, which help to release their bones. Then after, involved bone has been moved and transported by heavy rainfall to the fluvial channels. During flooding, the fluvial system has high flow regime, high velocity and high energy of transportation and can transport the large and small bones together with sand, gravel, and mud balls within bed loads and deposited as channel lag sediments. Beside to the volcanic activities like tuff stones, glass shards, pyroclastic crystals and tuffaceous rocks. The involved bed load may be reworked in many cycles of deposition and finally deposited on the erosional surfaces to form the lower part of point bar within fining upward cycles of the fluvial environment of the Mukdadiya Formation (Late Miocene – Pliocene). The lower part of a point bar is characterized by trough and planner cross-bedded coarse sandstone followed by medium cross-bedded sandstones to form the middle part of a point bar. Finally, laminated fine sands and silts have been deposited to form over bank deposits or upper part of point bar.

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