

REVIEW ARTICLE

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# A Review on Taxonomy and Distribution of the Genus *Echis* Merrem, 1820 (Serpentes: Viperidae) with Special Reference to the Middle East

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(Received: 30 August 2023; Accepted: 10 November 2023)

## Abstract

Saw scaled vipers of the genus *Echis* belong to the family Viperidae and subfamily Viperinae. These vipers are widely distributed from East Africa to Southwest and Central Asia. *Echis* bite is one of the major causes of mortality in the world. Different populations of these medically important snakes have different venom composition, and the relevant antivenom is highly species-specific. *Echis* has a complex taxonomic history. For many years, only two species were recognized (i.e., *Echis coloratus* and *E. carinatus*). Over the past 50 years, the number of species have been raised to 12, of which six species reside in the Middle East. Phylogenetic studies show that the genus *Echis* fall into four species groups: the *E. carinatus*, *E. coloratus*, *E. ocellatus* and *E. pyramidum* groups. Until recently, only *E. carinatus* in Southwest Asia and India and *E. coloratus* in Arabia were assigned to the Middle East. Several morphological and phylogenetic studies raised the number of *Echis* species in the Middle East from two to six. These Middle Eastern vipers belong to three different species groups. An Asian, an Arabian and an African group. Distribution and basal split of the genus *Echis*, likely have been shaped by vicariance and tectonic events, which have separated or connected the land masses. In this study, a brief review on biogeography, taxonomy and distribution of the genus especially in the Middle East is presented.

**Key words:** *Echis*, the Middle East, Phylogeny, Saw Scaled Viper, Taxonomy

## INTRODUCTION

The carpet vipers of the genus *Echis* Merrem, 1820 belonging to the family Viperidae and subfamily Viperinae, are well adapted to living in arid and semiarid regions. They are distributed extensively across Africa, north of the Equator, Arabian Peninsula, Jordan, Palestine, Israel, United Arab Emirates, Oman, Iraq, Iran and toward north and east to Turkmenistan, Uzbekistan, Afghanistan, Pakistan, India, Sri Lanka and Bangladesh (Leviton et al., 1992; Joger, 1984; Ananjeva et al., 2006; Arnold et al., 2009).

*Echis* is also known as saw scaled viper as they have scales with serrated keels and when they are threatened, they rub their body parts together and make a sizzling sound instead of hissing. Some believe



that this respond is an adaptation, preventing loss of water due to hissing, as their habitat is arid and semiarid regions (Mallow et al., 2003).

*Echis* has a strong virulent venom and the LD 50 is 5.1mg/kg in humans (Daniel, 2002). In many areas such as Africa and especially in West Africa *Echis* bite causes death. About 20,000 *Echis* bite deaths annually has been recorded for the whole Africa (Chippaux, 1998, 2006). In some African countries such as Nigeria the most snake bite mortalities are related to *Echis* bites, about 12% (Warrell, 2013). *Echis* bite is also one of the major causes of mortality in India (Bhat, 1974; Kochar et al., 2007; Arnold et al., 2009; Pook et al., 2009) and in the world as well (Oldfield, 2021). Although hemorrhage, local necrosis, blood coagulation and local blistering are the same clinical symptoms in all the patients bitten by *Echis*, but the venom compositions vary among different populations of *Echis*, remarkably.

Therefore, the antivenom is highly species-specific (Arnold et al., 2009). Since this viper is widely distributed and is highly dangerous, therefore leaving aside the issue of conservation, knowing the exact taxonomic status and distribution range of the *Echis* species can lead specialists to produce more effective antivenom and reduce mortality rate caused by *Echis* bite. The classification scheme of this genus is as follows:

### **Family Viperidae Opperl, 1811**

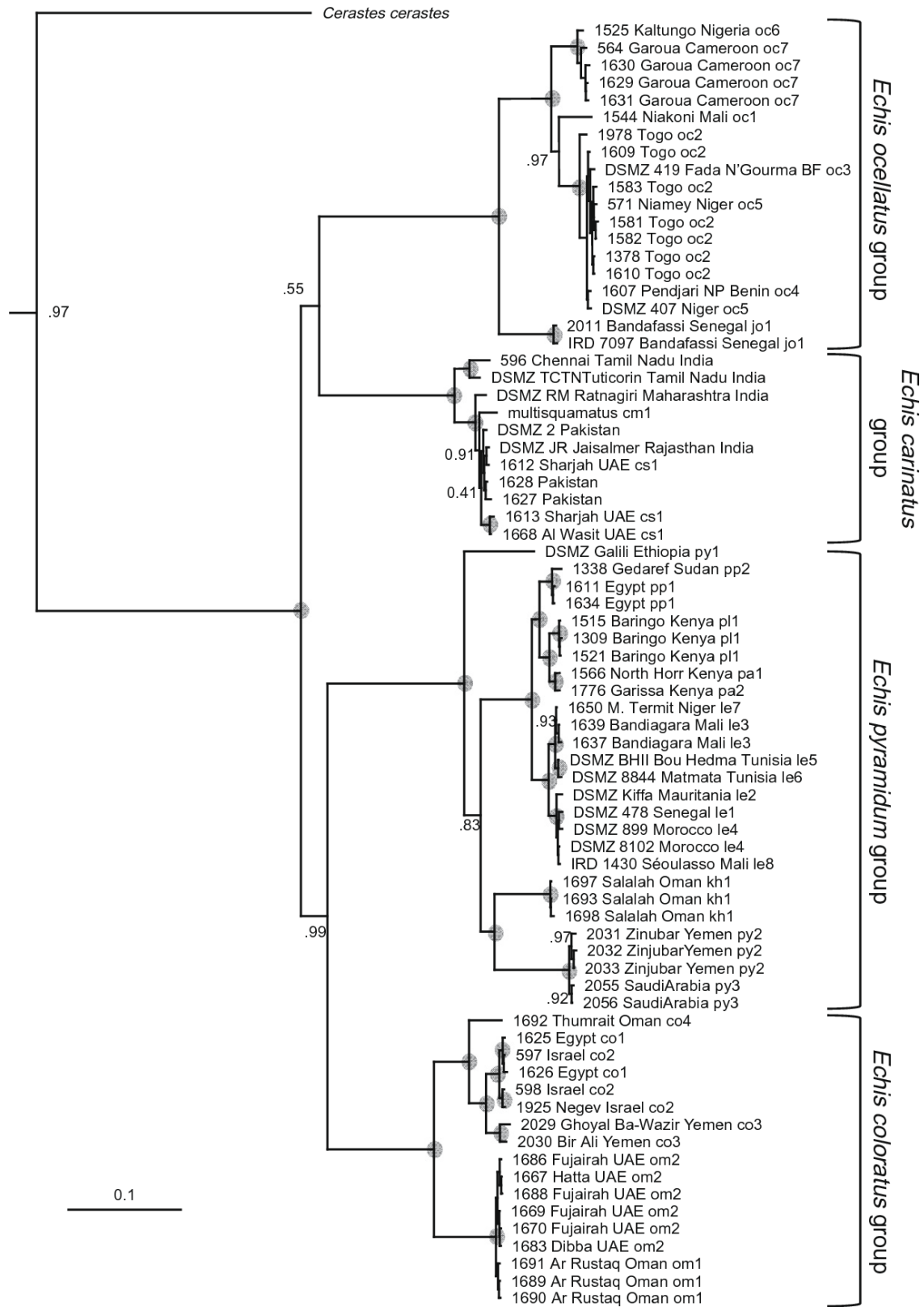
#### **Subfamily Viperinae Opperl, 1811**

#### **Genus *Echis* Merrem.1820**

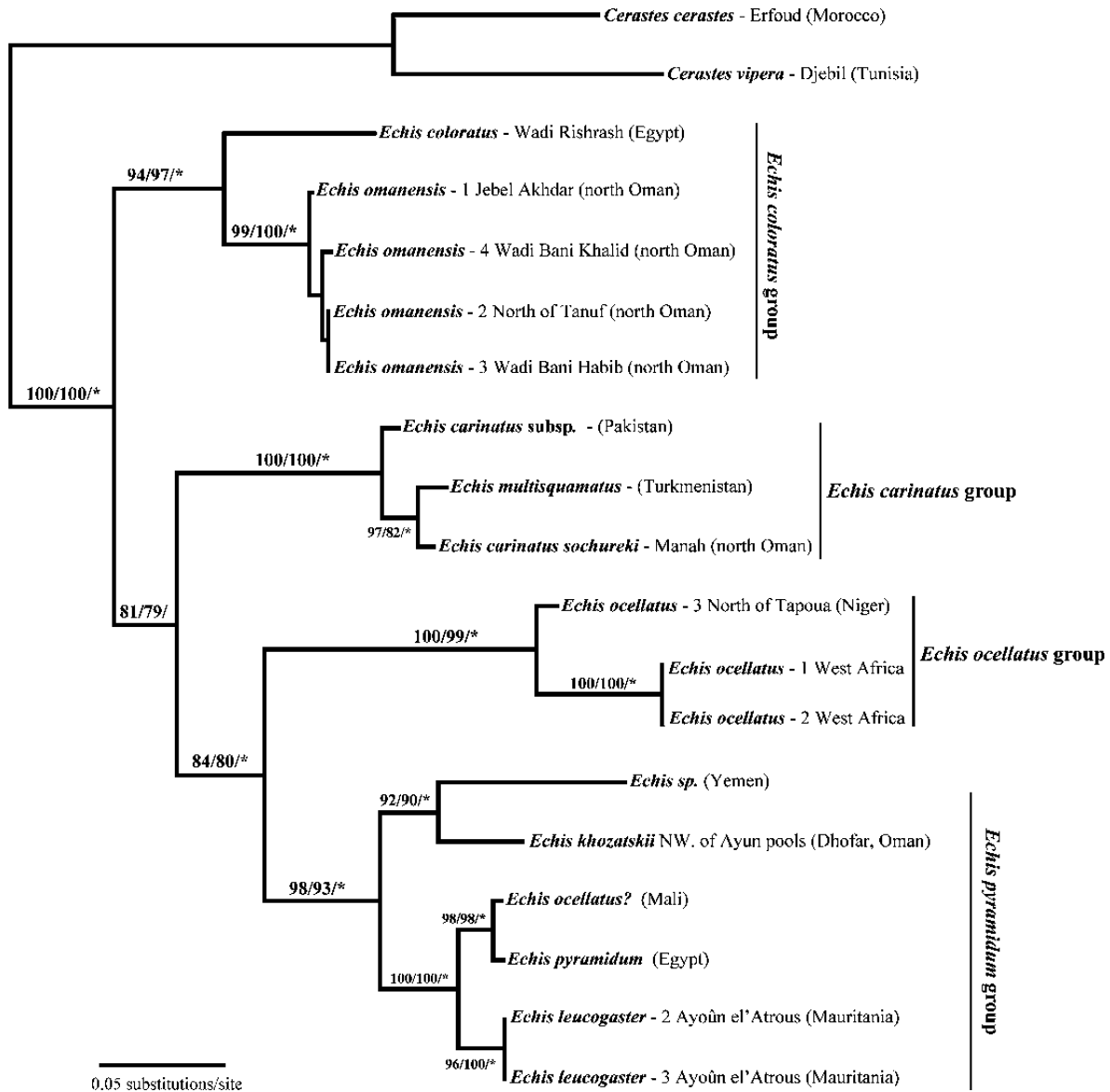
*Echis* has a long history of taxonomic confusion and controversy (David & Ineich, 1999; Mallow, 2003; Pook et al., 2009). Much debate in taxonomy of *Echis* has been over past 50 years. For many years, only two species were recognized. Klemmer (1963) reported two species: *E. coloratus* (Günther, 1878) in Jordan, Lebanon, Israel, eastern Egypt and Arabia and *E. carinatus* (Schneider, 1801) in most of the distribution range of the genus. Joger (1984, 1987) raised the number of species to three and added *Echis pyramidum* (Geoffroy Saint-Hilaire, 1827) for southwestern Arabia. Cherlin (1990) described three subgenera, 12 species and 20 subspecies but not many researchers accepted all these arrangements (Auffenberg & Rehman, 1991; Schätti & Gasperetti, 1994; Trape & Mané, 2006; Pook et al., 2009; Uetz et al., 2022). David and Ineich (1999) described eight species. Mellow et al. (2003) described 10 species and Pook et al. (2009) clarified some complicated and unresolved taxonomic situations between species by using molecular methods. Therefore, there was no single opinion on phylogeny and taxonomy of the genus *Echis* (Mazuch, 2005).

Until recently much of our understandings of phylogeny and taxonomy of *Echis* were based on morphological studies. The first comprehensive molecular study about the phylogeny of the genus *Echis* was done by Pook et al. (2009). They used four mitochondrial markers in this study and their results showed the populations of *Echis* are divided into four main species groups, the *E. carinatus*, *E. ocellatus*, *E. pyramidum*, and *E. coloratus* groups (Fig. 1). They also resolved interrelationships among these four species groups, although incompletely. Their analyses supported the *E. coloratus* and *E. pyramidum* groups as sister groups, but relationship between the *E. coloratus* and the *E. carinatus*-*E. ocellatus* groups remained unresolved (Pook et al., 2009).

Barlow et al. (2009), by using the mitochondrial and nuclear genes and only one specimen for each species complex, showed that the *E. carinatus* complex is the sister group of other complexes and the *E. ocellatus* group is the sister group to the *E. pyramidum*-*coloratus* lineage. In 1990, Cherlin suggested three subgenera for *Echis* i.e., *Echis*, *Turanechis* and *Toxicoa*, but phylogenetic study by Pook et al. (2009) showed that these three subgenera were non-monophyletic and they rejected this arrangement. They also showed that *Echis* and *Cerastes Laurenti*, 1768 are monophyletic and sister-group. This sister-group relationship between *Echis* and *Cerastes* was suggested by Joger and Courage (1999) and also by Wüster et al. (2008). According to phylogenetic analysis of mtDNA genes, Arnold et al. (2009) indicated four main clades for *Echis* as well i.e., *E. ocellatus*, *E. carinatus*, *E. coloratus* and *E. pyramidum* groups (Fig. 2).



**FIGURE 1.** Bayesian inference tree of the genus *Echis*. Nodes with gray circles received a Bayesian Posterior probability (bpp) of 1.00 (from Pook et al. 2009).



**FIGURE 2.** Relationships of the genus *Echis* using cytochrome b and 16S rRNA mitochondrial genes based on Arnold et al. (2009). Figures close to nodes are maximum likelihood bootstrap value/maximum parsimony bootstrap value/ Bayesian posterior probability value (only values equal or higher than 0.95 are indicated with an asterisk “\*”).

### Phylogeny of the snakes of the Genus *Echis* Merrem, 1820

#### *Echis* Merrem, 1820 Synonyms:

*Scythale* I. Geoffroy-Saint-Hilaire, 1827 (nomen emendatum), *Toxicoa* Gray, 1849a, *Enchis* Haltom, 1931 (nomen incorrectum), *Ecchis* Rosenfeld, Kelen & Nudel, 1964 (nomen incorrectum), and *Turanechis* Cherlin, 1990 (Wallach, 2014).

**Type species:** *Pseudoboa carinata* Schneider, 1801.

For the first time Schneider (1801) described *Echis carinatus* under the name of *Pseudoboa carinata* from Madras, eastern India. Geoffroy Saint Hilaire (1827) described *Scytale pyramidium*, now called

*E. pyramidum*, from Egypt. Gunther (1878) distinguished *E. arenicola* (now called *E. coloratus*) from Arabia. In 1949, Constable referred snakes from northern India to *E. carinatus pyramidum*. Deraniyagala (1951) described *E. carinatus sinhalensis* from Sri Lanka. In 1930, Chernov noted that vipers from central Asia and Iran are different from the vipers of Egypt but he did not have satisfactory samples of these snakes from Africa available to reach authoritative conclusions (Cherlin, 1984). From 1970 onwards, many papers allocated to the taxonomy of these vipers were published. Stemmler and Sochurek described *E. carinatus leakeyi* from Lake Daringo in Kenya (Stemmler & Sochurek, 1969; Cherlin, 1984), at the same time Stemmler (1969) distinguished *E. carinatus sochureki* from central Asia and the adjacent regions. Mertens in 1970, introduced *E. carinatus astole* from the Astole Island in Pakistan. *E. carinatus ocellatus* was described in that time from the Gulf of Guinea by Stemmler (Stemmler, 1970; Cherlin, 1984). In 1972, Roman distinguished *E. carinatus leucogaster* from south of the Sahara (Roman, 1972) and, three years later he declared that this was a new species named *E. leucogaster* (Roman, 1975). Drewes and Sacherer (1974) identified *E. carinatus allaborri* from Kenya. *E. ocellatus* was described as a separate species by Hughes (1976) from West Africa. It was defined as a subspecies of the *E. carinatus*. In 1981 *E. multisquamatus* was introduced by Cherlin from central Asia and the adjacent regions (Cherlin, 1981). In 1990, Cherlin described 12 species of which only five species are now accepted. *E. varia borkini* (now known as *E. borkini* Cherlin, 1990) from Yemen and Saudi Arabia, *E. hughesi* Cherlin, 1990 from Somalia, *E. jogeri* Cherlin, 1990 from West Africa, Gambia, Mali and Senegal, *E. khosatzkii* Cherlin, 1990 from Yemen and Oman and *E. megaloccephalus* Cherlin, 1990 from Eritrea. In 2004, Bobocsay reported a population of *E. coloratus* as *E. omanensis* Babocsay, 2004 from the UAE and Oman. Finally, Trape described *E. romani* trape, 2018 from Cameroon, Chad, Niger and Nigeria (Trape, 2018). This newly described species was formerly a population of *E. ocellatus* Stemmler, 1970. Although there is a consensus on 12 species of the Genus *Echis* as of now, studies are still underway to identify and describe new species and subspecies in different regions. The species of the genus *Echis* that are today approved by most researchers are as follows (Uetz et al., 2022):

*Echis borkini* Cherlin, 1990  
*E. carinatus* (Schneider, 1801)  
*E. coloratus* Günther, 1878  
*E. hughesi* Cherlin, 1990  
*E. jogeri* Cherlin, 1990  
*E. khosatzkii* Cherlin, 1990  
*E. leucogaster* Roman, 1972  
*E. megaloccephalus* Cherlin, 1990  
*E. ocellatus* Stemmler, 1970  
*E. omanensis* Babocsay, 2004  
*E. pyramidum* (Geoffroy Saint-Hilaire, 1827)  
*E. romani* Trape, 2018

As explained before the taxonomy of the Genus *Echis* has been in flux especially in Africa. However, in this article, we discuss the taxonomy of the genus *Echis* in the Middle East.

### ***Echis* in the Middle East**

Until recently, only two species of *Echis* were assigned to the Middle East. *Echis carinatus* in Southwest Asia and India and *E. coloratus* in Arabia. In 1984, and 1987, Joger described *E. pyramidum* from Arabia (southwestern regions) and after that, scientists described new species and subspecies especially in the *E. coloratus* group. After 25 years of research and based on other scientists' results, Stümpel and Joger (2009) raised the number of *Echis* species in the Middle East from two to six. These vipers belong to three different species groups. An Asian, an Arabian and an African group. The Middle Eastern species recognized by Stümpel and Joger (2009) are as follows:

*Echis carinatus* group (Asian group):

- *E. carinatus* (Oman, UAE, Iran, Central Asia, Afghanistan, Pakistan)

*Echis coloratus* group (Arabian group):

- *E. coloratus* (Egypt, Arabian Peninsula)
- *E. omanensis* (Oman, UAE)

*Echis pyramidum* group (one of two African groups):

- *E. pyramidum* (Egypt, Sudan, East Africa)
- *E. khosatzkii* (western Oman, Yemen)
- *E. borkini* (Yemen, SW Saudi Arabia)

### ***Echis carinatus* (Schneider, 1801)**

*Pseudoboa carinata* Schneider 1801: 285, *Boa Horatta* Shaw, 1802, *Scytale bizonatus* Daudin, 1803, [*Vipera* (*Echis*)] *carinata* Merrem 1820. *E. carinata* Duméril & Bibron 1854: 1448. *E. carinatus* Mith 1943: 487, *E. carinatus sinhaleyus* Deraniyagala 1951: 148. *Echis carinatus* Latifi, 1978. *Echis carinatus* Harding & Welch 1980. *Echis multisquamatus* Cherlin 1981. *Echis carinatus* McDiarmid, Campbell & Touré 1999: 376. *E. carinatus sinhaleyus* David & Ineich 1999, *E. carinatus multisquamatus* David & Ineich 1999. *Echis multisquamatus* Ananjeva et al. 2004. *E. carinatus sochureki* Dobiey & Vogel 2007. *Echis multisquamatus* Rastegar-Pouyani et al. 2008. *E. carinatus sochureki* Afrasiab 2011, *Echis carinatus* Wallach et al. 2014: 255. *E. carinatus astolae* Khan 2017 (Uetz et al., 2022).

**Type locality:** Yavatmal, Maharashtra State (Arni), West India. No type locality available (fide LOVERIDGE 1936). Type locality (fide SCHMIDT 1939): “Arni” [= Aarni, Yavatmal, Maharashtra, India], (20.073345, 77.954673) (Uetz et al., 2022).

**Distribution:** Southwest and South Asia. United Arab Emirates, Qatar, Oman, Iraq, Iran, Uzbekistan, Turkmenistan, Tajikistan, Afghanistan, Pakistan, India, Bangladesh and Sri Lanka (O’Shea, 2018).

*Echis carinatus* is a member of the *Echis carinatus* group (one of the four *Echis* species groups) which is completely an Asian group. *Echis carinatus* has five subspecies as follows:

The nominate subspecies *E. c. carinatus* (Schneider, 1801) in peninsular India, the widely distributed subspecies *E. c. sochureki* Stemmler, 1969 in Pakistan, Iran, Iraq, Bangladesh, Afghanistan and the United Arab Emirates. Population in Astola Island in Pakistan, under the name of *E. c. astolae* Mertens, 1970 and population in Sri Lanka, under the name of *E. c. sinhaleyus* Deraniyagala, 1951 (O’Shea, 2018). Some Russian herpetologists believe that another species that is called *Echis multisquamatus* cherlin, 1981 occurs in the Central Asia, East of Iran and some parts of western Afghanistan and Pakistan (Ananjeva et al., 2006). Some consider it as a subspecies of *E. carinatus* : *E. c. multisquamatus* Cherlin, 1981 (David & Ineich, 1999; O’Shea, 2018).

### ***Echis carinatus sochureki* Stemmler, 1969**

#### **Sochurek's saw-scaled viper, Sindh Saw-scale Viper**

**Diagnosis:** Small-sized viper (35-55 cm), head broad and pear-shaped. Ground color brown or gray, white vertebral patches, which may be diagonal. Lateral zigzag with pale arcs, within each arc a single dark spot. Pale cross on head or backwards facing trident on a dark background. Ventral white or gray with dark medial spots. Mid-body scale rows: 25–33, keeled; ventrals: 155–175, wide; anal undivided; subcaudals: 29–48, entire. Circumorbitals: 14–20; scale rows between eye and upper labials: 2–3; upper labials: 10–12 (rarely 13); small imbricate scales on top of head. From sea level to 2000 m, ovoviviparous (Egan, 2022).

***Echis coloratus* Günther, 1878****Palestine Saw-scaled Viper, Burton's carpet viper**

*Echis froenata* Duméril, Bibron & Duméril, 1854: 1449 (nomen oblitum), *Echis frenata* Pfeffer, 1893, *Echis coloratus* Boulenger, 1896, *Echis coloratus coloratus* Cherlin, 1983, *Echis coloratus* Haas, 1957: 83, *Echis coloratus* Gasperetti, 1988, *Echis [(Turanechis)] froenatus* Cherlin, 1990, *Echis froenatus* Cherlin & Broklin, 1990, *Echis coloratus* Welch, 1994: 57. *Echis coloratus* Mcdiarmid, Campbell, Campbell & Tour, 1999: 378, *Echis coloratus* Doherty & Vogel, 2007, *Echis coloratus* Pook et al. 2009, *Echis coloratus* Wallach et al. 2014:255, *Echis coloratus* Meiri et al. 2019. *Echis coloratus terraesanctae* Babocsay 2003. *Echis coloratus terraesanctae* Bar & Haimovitch 2011: 192 (Uetz et al., 2022).

**Type locality:** Jebel Sharr, behind El Mewaylah, in Midian, at an elevation of 4500 feet. Holotype: BMNH 1946.1.20.84 (Babocsay, 2003; Uetz et al., 2022).

**Distribution:** Eastern Egypt, Yemen, Saudi Arabia, Israel, Southern Oman, Jordan.

**Diagnosis:** ventrals: 175–204, subcaudals: 45–56, nasal almost never fused with the upper prenasal, lower prenasal usually present, 3.5–7.5 scales between the chin-shield and the preventral, conspicuously elongated gulars along the two sides of the midline of the throat. Head dorsally usually uniform gray, mostly with an X-shaped marking, rarely spots. Facial band covers from 17–38 temporal scales, facial band often abruptly ends before the postmandibular blotch, mostly merges with it, usually dark bands below the eye and often fuse with each other or with the facial band, Grows to 716 mm RA, tail relatively long (15.0 in male and 13.0 in female) (Babocsay, 2004).

**Remarks:** The viper was described for the first time under the name *Echis froenata* Duméril, Bibron et Duméril, 1854. However, since this name had not been used more than 100 years, Stimson (1974) suggested that the International Zoological Commission nomenclature (IZCN) use *E. coloratus* as the valid name. Therefore, *Echis froenatus* should be regarded as a nomen oblitum (Uetz et al., 2022). *E. coloratus* is nested in the *E. coloratus* complex (Arnold et al., 2009; Pook et al., 2009), which was considered as a taxonomically integral species by Cherlin (1990) and Joger (1984). Therefore, studies on taxonomy of this species were abated, and researchers mostly focused on other African and Asian populations of *Echis*. Until Babocsay (2003) realized that, the populations of *E. coloratus* in Levant and Arabia were greatly different. He noticed that there are two variants of *E. coloratus* population in Israel, which differ in color and pattern. The northern variant, in Sinai and toward Arava Valley, with reddish brown or pink ground color, has large dorsal blotches in light pink. The blotches on the sides are shaded as light gray or blue by a dark frame enclosed them. The southern variant, occurring in the central Dead Sea area northwards, with gray or brown-grounded color, has large not framed blotches in light gray or brown. Moreover, several dark dots attached to blotches are recognizable. So, he analyzed these variants and assigned the northern Levantine *E. coloratus* population as a new subspecies (Babocsay, 2003).

***Echis coloratus coloratus* Günther, 1878**

**Diagnosis:** A medium-sized viper, bumps on the keels of the dorsal scales, unenlarged inframandibular scales, and 3-4 rows of scales between the eye and supralabialia. Drawing bland with large light circular-oval spots on the dorsal surface of the body. The pattern on the head is indistinct or absent. It differs from its closest relative *Echis coloratus terraesanctae* Babocsay, 2003 by more ventral plates, fewer dorsal ones, color and relatively larger eyes (Babocsay, 2003).

**Distribution:** It occurs in northwestern Arabia (Midian), in the southern Levant and in Egypt, east of the Nile. There is a hybrid zone with *E. c. terraesanctae*. The populations of *E. coloratus* in the Arabian Peninsula are different from the typical *E. coloratus* in coloration form, and need to be taxonomically studied (Babocsay, 2003).

***Echis coloratus terraesanctae* Babocsay, 2003****Holy land saw scaled viper**

*Echis colorata* Günther 1878:978 (Type locality: Jebel Sharr, Midian; Coll: Sir Richard Burton); Flower 1933:835 (part). *Echis coloratus*, Boulenger 1896:507, pl. 25, fig. 1 (Dead Sea); Anderson 1898:343; Joger 1984:46 (part); Gasperetti 1988:348 (part); Leviton et al. 1992:114 (part); Babocsay 2003 (part). *Echis froenatus* Duméril, Bibron et Duméril 1854; Cherlin 1990: 203 (part, taxonomic review, map; the name was suppressed by Opinion 1176 [ICZN 1981]) (Babocsay, 2003; Uetz et al., 2022).

**Type locality:** Ma'ale Efrayim, Samaria, Cisjordan; coll: Y. L. Werner et al. on 26.3.1980. Holotype: HUI R 8926 (Babocsay, 2003).

**Distribution:** It distributed in the northern and central Dead Sea basin, the Jordan Valley and their western slopes (Babocsay, 2003).

**Diagnosis:** According to Babocsay (2003), *Echis coloratus terraesanctae* differs from *E. c. coloratus* in the southern Levant in its lower ventral count and higher number of dorsal scale rows on all sections of the body, in colour pattern and in its relatively larger eyes.

***Echis omanensis* Babocsay, 2004****Oman saw-scaled viper**

*Echis colorata* Gunther: Boulenger, 1887:408 (Muscat; coll: A. S. G. Jayakar). *Echis coloratus* Gunther: Boulenger, 1896:507 (Muscat; coll: A. S. G. Jayakar); Arnold and Gallagher, 1977:69 (Wadi Serin and Wadi Kebir); Joger, 1984:46 (part, locality resume and map); Gasperetti, 1988:348 (part, locality resume and map). *Echis froenatus* Dumeril, Bibron et Dumeril: Cherlin 1990:203 (part, taxonomic review, map; the name was suppressed by Opinion 1176 (ICZN 1981) (Uetz et al., 2022).

**Type locality:** Wadi as Siji, region of Masafi (25°18\_x0005\_N 56°10\_x0005\_E), United Arab Emirates. Holotype: BMNH 1973.2113 (Babocsay, 2004; Uetz et al., 2022).

**Distribution:** The species distributes in the United Arab Emirates and north of Oman and ranges from sea level to 1000 m (Babocsay, 2004).

Babocsay (2004) noticed that the species seems to be mostly active in the spring months in the morning and in the afternoon and evening, but less active in autumn. However, In Israel, *E. coloratus* is active in other season as well, particularly in summer. He also found that use of gularis scales is a useful character at the species level, and interestingly the gular area has varied characters in which the variation is correlated. Formerly Cherlin (1983) had used the variation in gular shape and size to divide *Echis* genus into subgenera (Cherlin, 1990; Babocsay, 2004).

By studying a large number of specimens from entire range of the *E. coloratus* complex, Babocsay (2004) described a new species from northern Oman and the United Arab Emirates under the name of *Echis omanensis* Babocsay, 2004. In fact, the new species is separated from the rest of snakes in the *E. coloratus* complex by an extended geographic barrier, the Rhub al Khali Desert in south and southwest part of Arabian Peninsula. As *E. coloratus* is arenicolous, it doesn't inhabit sandy habitats, so Babocsay (2004) believed that this taxonomic discontinuity and allopatric speciation make sense.

Babocsay (2001), also studied samples from lands around this geographic barrier that were morphologically different. Besides, some authors have shown that snakes in the *E. coloratus* complex had greatly different intraspecific coloration (Gasperetti, 1988; Kochva, 1990; Mendelssohn, 1965). Thereby, different morphological traits and geographic isolation of the populations of the *E. coloratus* complex in



its expansion range shows that this complex has a separate evolutionary background (Babocsay, 2004). *Echis omanensis* is different from *E. coloratus* as follows:

Longer tail (16.3) with higher subcaudal counts (49–58); the lower prenasal scale is often missing and the upper prenasal is frequently fused with the nasal; the subnasal is often missing or fused with the nasal. The gular scales between the chin-shield and the preventrals are round or only slightly elongated, not elongated as in *Echis coloratus*, and their number is higher. Ventrals: 184–194, subcaudals: 49–58, Head dorsally usually uniform gray, rarely a dark X-shaped marking or, in young specimens marked by small spots. Ground colour of the body gray with dark edged, conspicuous dorsal blotches; the dark frame may surround the entire blotch or may partly disappear, remaining only laterally and as two transversally positioned spots across the mid-dorsal line, one at the caudal end, one at the cranial end of the blotch. Ventral surface yellowish-white or grayish-white, mostly with a faded line of dots medially and an array of faded dots toward each lateral side of the ventrals or with only one of these components; it may lack any pattern. Grows to 606 mm (rostrum-anus) (Babocsay, 2004).

***Echis pyramidum* (I. Geoffroy Saint-Hilaire, 1827)**

**Northeast African Carpet Viper, Egyptian Saw-scaled Viper**

*Scythale pyramidum* Geoffroy Saint-Hilaire 1827: 152. *Echis arenicola* Boie 1827. *Echis pavo* Reuss 1834: 157. *Echis varia* Reuss 1834: 160. *Echis arenicola* Strauch 1868: 292. *Echis carinatus pyramidum* Ionides & Pitman 1965. *Echis carinatus pyramidum* Harding & Welch 1980. *Echis varius darevskii* Cherlin 1990. *Echis (Toxicoa) pyramidum lucidus* Cherlin 1990. *Echis varius* Largen & Rasmussen 1993, *Echis arenicola* fide David & Ineich 1999. *Echis pyramidum* Mediarmid, Campbell & Touré 1999: 380. *Echis carinatus pyramidum* Khan 2002 (pers. comm.), *Echis pyramidum* Pook et al. 2009, *Echis arenicola* Gruber 2009, *Echis varius (pyramidum)* Mazuch 2013, *Echis pyramidum* Wallach et al. 2014: 256, *Echis varius* Wallach et al. 2014: 256, *Echis pyramidum* Spawls et al. 2018: 582 (Uetz et al., 2022).

**Distribution:** North Africa, Egypt, Somalia, Ethiopia, Eritrea, Sudan, Libya, Tunisia, southwest Arabian Peninsula.

**Type locality:** Cairo, Egypt. Holotype: MNHN-RA 4031, according to Hughes (1976, Rev. Suisse Zool. 83: 361) (Uetz et al., 2022).

**Taxonomy:** The species resides in the most complex species group in the genus *Echis*. Both taxonomically and phylogenetically, it has shown a great deal of diversity. And so far, it has gone through different species and subspecies levels (Pook et al., 2009). Cherlin (1990), in an extensive revision study of the genus, splits *E. pyramidum* in many species or subspecies: *E. p. pyramidum*, *E. p. lucidus*, *E. p. leakeyi*, *E. varius*, *E. v. darevskii*, *E. v. borkini*, *E. v. aliaborri*, *E. hughesi* and *E. megalcephalus* from north and east Africa, *E. varius borkini* and *E. khosatzkii* from southwest Arabia. Schätti and Gasperetti (1994), questioned Cherlin's work, considering *E. varius* a distinct species from *E. pyramidum*. McDiarmid et al. (1999), declared most of these subspecies are synonyms of *E. pyramidum*. But the status of *E. varius* as a separate species or subspecies is in doubt and needs more verification (Pook et al., 2009; Wallach et al., 2014). About *E. borkini* and *E. khosatzkii*, we will discuss their status in the following. Phylogenetic analysis of populations of this complex showed that out of four clades forming the complex, two are Arabic and two are African with significant divergence. *E. borkini* and *E. khosatzkii* are nested in Arabic clades and *E. p. pyramidum*, nested in one of two African clade (Arnold et al., 2009; Pook et al., 2009; Stümpel & Joger, 2009). Currently *E. pyramidum* has two subspecies; *E. p. pyramidum* (Geoffroy Saint-Hilaire 1827) from Egypt, southwest Saudi Arabia, Somalia, Ethiopia, Sudan and *E. c. leakeyi* Stemmler and Sochurek 1969 from Kenya, southern Somalia, and southern Ethiopia.

A brief description of *E. p. pyramidum* is as follows:

***Echis p. pyramidum* (Geoffroy Saint-Hilaire 1827)**

**Diagnosis:** A medium sized viper (40-50 cm), ground color gray-brown, pale vertebral blotches, large dark spots surrounding with inverted V-shape below dorsal blotches, creating zigzag on flanks. Dark spots near ventral margin. A pale arrow like marking on a dark ground on head. Dark line from eye to posterior labials. White ventral. Dark stripe from eye to posterior labials. Dark line from eye to posterior labials. Mid-body scale rows: 27–31, keeled. Ventrals: 167–186, wide; anal: single; subcaudals: 31–38, undivided. Scale rows between eye and upper labials: 2–3; upper labials: 10–13; lower labials: 9–13; interorbitals: 9–12; circumorbitals: 17–21; medium imbricate scales on top of head (Egan, 2022).

**Distribution:** Egypt, southwest Saudi Arabia, from below sea level to 500m.

***Echis borkini* Cherlin.1990****Borkin's Carpet Viper**

*Echis varius borkini* Cherlin 1990, *Echis borkini* Schätti 2001, *Echis borkini* Pook et al. 2009, *Echis borkini* Stümpel & Joger 2009, *Echis borkini* David & Vogel 2010, *Echis borkini* Wallach et al. 2014: 254 (Uetz et al., 2022).

**Distribution:** Southwest Arabia, western Yemen.

**Type locality:** Lahej near Aden in Yemen. Holotype: BMNH 99.20.5.18 (Uetz et al., 2022).

**Diagnosis:** a small to medium sized snake (40-50 cm), ground color light brown, darker dorsally, oval shaped vertebral blotches, as wide as interspaces, to the tip of tail. Vertebral may be divided into paired paravertebral blotches, sometimes has flat zigzag on flanks, small dark spots (usually brown) near ventral edge, an indistinct dark patch with a bright center on head, ventral white. Mid body scale rows: 27-31, keeled, ventrals: 155-181, anal: undivided, subcaudals: 31-44, entire, scales rows between eye and upper labial: 1-2, upper labial: 10-13, lower labial:9-13, interorbitals: 10-12, circumorbitals: 16-20 (Egan, 2022).

**Habitat:** sandy coastal dunes with vegetation (below 200m). Oviparous (Egan, 2022).

It may be mistaken for *E. coloratus* but *E. coloratus* has dorsally transverse blotches, and when seen from above its head becoming prominent behind eyes. Moreover these two species are not likely sympatric as *E. coloratus* dwells rocky areas and mountains, And in higher altitude (more than 2000 m) (Egan, 2022).

Cherlin (1990) described *Echis varia borkini* from the east Africa, southwest Arabia and western Yemen. Molecular data showed that populations of western Yemen are highly divergent from other species within complex in east Africa and Stumpel and Joger (2009) elevated the subspecies to a full species level as *E. borkini*. Phylogenetic studies by Arnold et al. (2009) and Pook et al. (2009) also showed that populations of western Yemen are genetically distinct from other populations within the *E. pyramidum* complex and considered it as *E. borkini*.

***Echis khosatzkii* Cherlin, 1990****Khosatzki's Saw-scale Viper**

*Echis khosatzkii* Cherlin 1990 (fide Golay et. al. 1993), *Echis khosatzkii* Cherlin 1990 (fide Mcdiarmid et. al. 1999), *Echis khosatzkii* Mallow et al. 2003, *Echis khosatzkii* Pook et al. 2009, *Echis khosatzkii* Arnold et al. 2009, *Echis khosatzkii* Stümpel & Joger 2009, *Echis khosatzkii* David & Vogle 2010. *Echis kozatskyi* Sindaco et al. 2013: 396 (in error), *Echis khosatzkii* Wallach et al. 2014: 255 (Uetz et al., 2022).

**Distribution:** Eastern Yemen, southern Oman.

**Type locality:** Arabia, Hadhramaut (eastern Yemen). Holotype: BMNH 97.3.11.117 (Uetz et al., 2022). (From sea level to 800m, oviparous)

**Diagnosis:** a small to medium sized viper (35–45 cm), ground color pale brown to pinkish, and reddish dorsally, pale vertebral lines or large V-shapes, smaller than or equal to brown interspaces, from neck to tail, pale zigzag on flanks with apex under which there is dark spot, unclear symmetrical head marks and triangular band from eye to posterior labials. Mid-body scale rows: 25–31, keeled, ventrals: 181–189, anal: undivided, subcaudals: 44–47, entire. Scale rows between eye and upper labials: 1–2 (rarely 3), upper labials: 10–13, lower labials: 9–13; circumorbitals: 17–21, scales on head small, ventral pearlish white to pale copper (Egan, 2022).

Cherlin (1990) in an extensive taxonomic study of the snake genus *Echis*, based on morphology recognized *E. khosatzkii* in the *E. pyramidum* complex from Yemen and Oman, which was previously assigned as *E. pyramidum* (Arnold et al., 2009). Arnold (1980) and Schätti and Gasperetti (1994) pointed out the great morphological differences of eastern populations with populations from the western and southwestern regions of Arabia. Phylogenetic study of Pook et al. (2009) confirmed their results, showing that two monophyletic Arabian and African clades in *E. pyramidum* complex are significantly different, and even populations within Arabian clade have diverged so that they represent two endemic Arabian species from south Oman and east Yemen and from west Yemen and southwest Arabia: *Echis khosatzkii* and *E. borkini*, respectively. The same results were obtained from Arnold's et al. (2009) and Stumpel and Joger's (2009) molecular studies.

## DISCUSSION

In the *Echis carinatus* group, we mentioned five subspecies but usually two of them are considered as valid subspecies; *E. c. carinatus* and *E. c. sochureki*. Most authors place *E. c. sinhaleyus* (in Sri Lanka) in the nominate subspecies. The Astola Island population, in Pakistan, is sometimes recognized as a subspecies (*E. c. astolae*), as is the Central Asian population (*E. c. multisquamatus*) (O'Shea, 2018). Morphological study of Auffenberg and Rehman (1991) showed that all the *Echis carinatus* populations across their expansion range have clinal variation. They assigned these populations as subspecies of *E. carinatus*. Molecular study of Lenk et al. (2001) showed low divergence between *Echis* population from Pakistan (*E. c. carinatus sochureki*) and Turkmenistan (*E. multisquamatus*). Bagherian and Kami (2008) in a morphological study showed that northern and eastern populations of Iranian *Echis* are different from southern populations. They considered the northern and eastern populations as *E. multisquamatus* and the southern populations as *E. carinatus*. On the other hand, phylogenetic study of Pook et al. (2009) showed that *E. multisquamatus* and *E. carinatus* are conspecific. Morphological study by Todehdehghan et al. (2019) showed that among populations of east, southeast and southwest Iranian *Echis*, southeast and east populations are closely related but they could not resolve the status of species or subspecies of populations. They also provided an identification key for these three populations. Rhadi et al. (2015) in a morphological study of *Echis* population in southern Iraq, near the border of Iran, showed that Iraqi populations are assigned to *Echis carinatus sochureki* but they suggested more ecological, morphological and molecular study in order to achieve the exact taxonomic status of the genus *Echis* in Iraq. Phylogenetic study by Rhadi et al. (2016) also supposed that Iranian *Echis*, which were not sampled in their study, nested between the eastern (India, Pakistan) and western (Iraq) populations and may be closely related to western ones. They also suggested that *E. carinatus* has originated in India and has spread towards west. This finding is in agreement with Pook et al. (2009) which suggested that current distribution pattern of *E. carinatus* is the result of diversification from south India. But Arnold et al. (2009) showed that Oman and southern Iran is center of origin of *E. carinatus* and then it has been diversified to east and west toward India and Iraq, respectively. The initial expansion of the genus *Echis* seems to be at the same time with the collision of Afro-Arabian and Eurasia. Moreover, divergence of the *E. coloratus* and *E. pyramidum* groups took place simultaneously with opening of the Red Sea. Distribution of the *E. pyramidum* groups was later influenced by land connections between Africa, Asia and Arabia especially through the Gomphotherium Landbridge about 18 mya (Rögl, 1999; Pook et al.,

2009). Phylogenetic studies by Pook et al. (2009) showed that there is low divergence between populations of north India, central Asia, northeast Arabia and the interstitial range so they concluded that *E. carinatus* diverged recently and rapidly, about 0.9 mya. During the Quaternary glacial maxima, the lowered sea level may have caused a land bridge between Arabian and Asian populations, and this has caused the rapid exchange of Arabian and Asian material. Rhadi et al. (2016) have proposed the same scenario.

Distribution and basal split of the genus *Echis* have been likely shaped by vicariance and tectonic events, which have separated or connected the landmasses (Pook et al., 2009). As Wuster et al. (2008) showed, the basal split within *Echis* dated back to 18.5 Mya, approximately coincide with the Gamphotherium Landbridge between Africa and Eurasia. Therefore, this genus can be considered as a model to study the effects of the collision of African-Eurasian on distribution of other organisms. As mentioned before *Echis* bite is one of the major causes of mortality in India and Africa (Bhat, 1974; Kochar et al., 2007; Arnold et al., 2009; Pook et al., 2009; Warrell, 2013), and the antivenom is highly species-specific (Arnold et al., 2009). Therefore, besides the biogeographical aspects, resolving the problematic taxonomy of this genus leads to higher efficiency of snakebite treatment (Pook et al., 2009). As a conclusion, a comprehensive morphological and phylogenetic study of these snakes is needed to provide a robust background for the genus origin, distribution routes and species delimitation. Undoubtedly, studying more samples from the southern and eastern regions of Iran can help to draw a better conclusion about the distribution of these species in the Middle East. Currently, the senior author of this article is studying samples from different regions of Iran for her PhD thesis, hoping to provide a detailed insight on taxonomic status and pattern of diversification of the genus *Echis* in Iran and subsequently in southwest Asia.

#### ACKNOWLEDGMENTS

We would like to thank all the reviewers of the article and the editorial team of the journal for their valuable guidance.

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