Vulcan's Slender Caecilian, *Caecilia volcani*, in Costa Rica

During the summer of 1966 Edward H. Taylor, at the age of 77, visited Panama to search for caecilians. Accompanied by Charles Myers, Edward Taylor traveled to the region of El Valle de Antón, located within a large, ancient volcanic crater. During their explorations in this region, Taylor and Myers discovered and collected 10 individuals of a slender caecilian in a soft muddy bank where a swampy area drained into a small stream. Edward Taylor went on to describe the specimens in this series as *Caecilia volcani* Taylor, 1969, named for the Roman god of fire and of smiths, Vulcan (Day, 2007).

Subsequent to the Taylor and Myers collection in El Valle de Antón, *C. volcani* has been collected at additional sites in western Panama, i.e., in La Fortuna (Wake et al., 2005), the vicinity of El Cope (Crawford et al., 2010), and Santa Fe (Köhler, 2011). *Caecilia volcani* currently is recognized as a species endemic to Panama.

The existence of a slender caecilian, often with a pale head, has been known from the Caribbean versant of Costa Rica for at least two decades, but the identification of this form unfortunately has been confusing, as this taxon erroneously has been referred to as *Dermophis parviceps* (Leenders, 2001: plate 1; Savage, 2002: plate 21; Kubicki, 2004; Köhler, 2011: fig. 20; Leenders, 2016: 27–28) despite the obvious morphological characters that disagree with the identification of this species (Dunn, 1924), the genus *Dermophis*, or even the family Dermophiidae (Wilkinson et al., 2011).

We performed a review of the phenotypic characteristics and an analysis of the 16S rRNA (16S) and cytochrome *b* (cyt *b*) mitochondrial genes of a specimen of this dubious caecilian (CRARC 0272), which was collected by BK in the Costa Rican Amphibian Research Center's Guayacán Rainforest Reserve. The tissue samples of CRARC 0272 were sequenced for a fragment of the 16S rRNA (16S) and cytochrome *b* (cyt *b*) mitochondrial genes using published primers and protocols (Kubicki and Arias, 2016; Kubicki, 2016). We compared our sample of CRARC 0272 with all the 16S and cyt *b* sequences available on GenBank for members of the genera *Caecilia* and *Dermophis* (Fig. 7). The individual alignments by gene were performed using the MUSCLE 3.7 software (Edgar, 2004) with default parameters, and trimmed to the point where a majority of the taxa had sequence data. We partitioned the sequence data by gene, and further partitioned cyt *b* by codon position. We used PartitionFinder v1.1.1 (Lanfear et al., 2012) and the Bayesian Information Criterion (BIC) to select an appropriate model of the DNA sequence evolution. The following substitution models were selected: GTR+G for 16S and for cyt *b* codon position 2, HKY+G for cyt *b* codon position 1, and HKY+I for cyt *b* codon position 3. The analyses were performed using both the maximum likelihood (ML) and Bayesian analyses. The ML analysis was performed using RAxML 8.1.11 (Stamatakis, 2014) and run on the CIPRES portal (Miller et al., 2010), including 1,000 bootstrap replicates to evaluate the nodal support. The Bayesian phylogenetic analyses were performed using MrBayes 3.2.2 (Ronquist et al., 2012). Two separate analyses were run, each consisting of 50 million generations, sampled every 1,000 generations, and four chains with default heating parameters. We examined a time-series plot of the likelihood scores of the cold chain to check stationarity using Tracer 1.6 software (Rambaut et al., 2014). We discarded the first 25% of the trees as burn-in, and used the remaining trees to estimate the consensus tree along with the posterior probabilities for each node and each parameter.

The resulting data matrix had a total sequence length of 1,336 bp, including gaps; 552 bp for 16S, and 784 for cyt *b.* The phylogenies inferred using ML and BA were concordant in supporting the tree shown in Fig. 7. The phylogeny shows CRARC 0272 to be conspecific with *Caecilia volcani,* confirming the presence of this taxon in Costa Rica. The discovery of *C. volcani* in Costa Rica results in a new country record for this species, which previously was considered endemic to Panama (Solís et al., 2008; AmphibiaWeb, 2017; Frost, 2017), and thus the total known diversity of amphibians in Costa Rica is 206 species (AmphibiaWeb, 2017).

The specimen of *C. volcani* used in this study (CRARC 0272; Fig. 1) strongly agrees with the diagnostic characters provided for this taxon by Taylor (1969: figs. 1, 2). *Caecilia volcani* (including CRARC 272) can be distinguished from *Dermophis parviceps* by the following characterstics (contrasting characteristics for *D. parviceps* are listed second): in *C. volcani* a chemosensory tentacle is positioned directly below the nostril (Fig. 2; Taylor, 1969: fig. 2) vs. sensory tentacle positioned about halfway between the eye and nostril (Fig. 3); grooves between the primary folds incomplete along the majority of the dorsum (Figs. 1, 6; Taylor, 1969: figs. 1, 2) vs. grooves between the primary folds complete, at least along the anterior dorsum (Fig. 4); and a pair of inner mandibular or splenial teeth is present (Fig. 5; Taylor, 1969) vs. inner mandibular teeth absent in the genus *Dermophis* (Wilkinson et al., 2011).

Over the last 15 years, *C. volcani* has been encountered on numerous occasions in the C.R.A.R.C.'s Guayacán Rainforest Reserve, most often while digging in muddy substrates or swampy soils. This species has been found in a variety of habitats, ranging from highly disturbed open areas, such as a yard, to mature secondary forest. The type series of *C. volcani* also was found in a muddy substrate (Taylor, 1969).

Over the years a minor but noteworthy level of phenotypic variation has been observed among the different individuals of *C. volcani* encountered in the reserve; the longest individual measured 430 mm in total length (measurement from a live individual), but most individuals encountered measured between 250 and 350 mm (B. Kubicki, pers. observ.). Additionally, a moderate level of chromatic variation also has been observed among different individuals of *C. volcani*, of which the most frequent chromatotype is a solid purple body with pale pinkish-purple coloration on the head (Fig. 6A). A nearly uniform coloration between the head and body is present in some individuals (Fig. 6C), but occasionally some with a mottled pale pink and purple coloration have been observed (Fig. 6B).

Following the confirmation of *C. volcani* within the C.R.A.R.C.'s Guayacán Rainforest Reserve, in addition to the photographic evidence presented in Leenders (2001: plate 1) and Savage (2002: plate 21), in which the captions state that the images are from a specimen(s) photographed at Rara Avis, a private biological reserve located near Horquetas on the northeastern slopes of Volcán Barva, the distribution of this taxon now is known to extend into the foothills of the central and northern Caribbean versant of Costa Rica.

Fig. 1. Different aspects of the anterior and posterior portions of a specimen of *Caecilia volcani* (CRARC 0272) collected in the yard of the Costa Rican Amphibian Research Center's Guayacán Rainforest Reserve, Guayacán de Siquirres, Provincia de Limón, Costa Rica. 📷 © Brian Kubicki

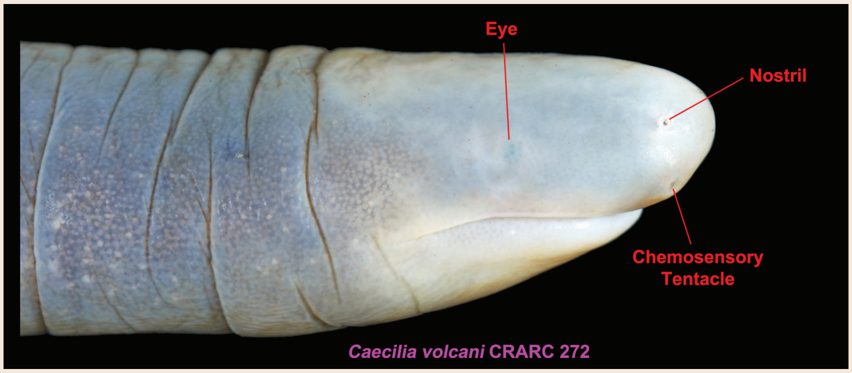

Fig. 2. View of the spatial relationships of the eye, nostril, and chemosensory tentacle on a specimen of *Caecilia volcani* (CRARC 0272) from Guayacán de Siquirres, Provincia de Limón, Costa Rica. 📷 © Brian Kubicki

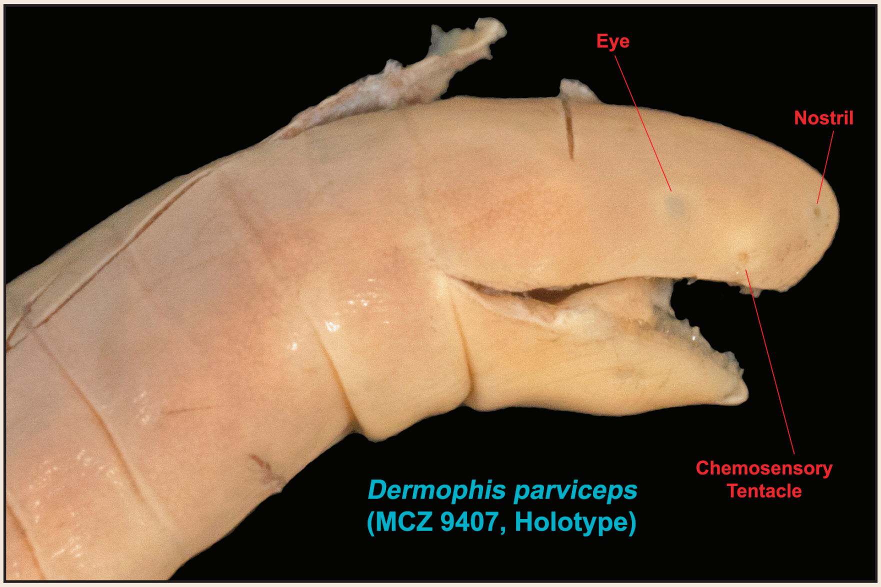

Fig. 3. View of the spatial relationships of the eye, nostril, and chemosensory tentacle on the holotype of *Dermophis parviceps* (MCZ 9407). 📷 © Joe Martinez (courtesy of the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, United States)

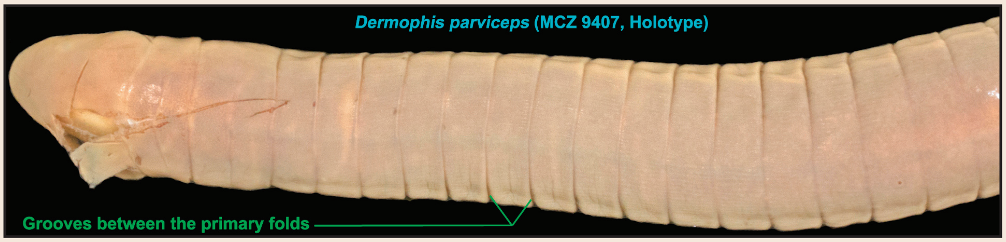

Fig. 4. View of the complete grooves between the primary folds on the dorsum of the holotype of *Dermophis parviceps* (MCZ 9407). 📷 © Joe Martinez (courtesy of the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, United States)

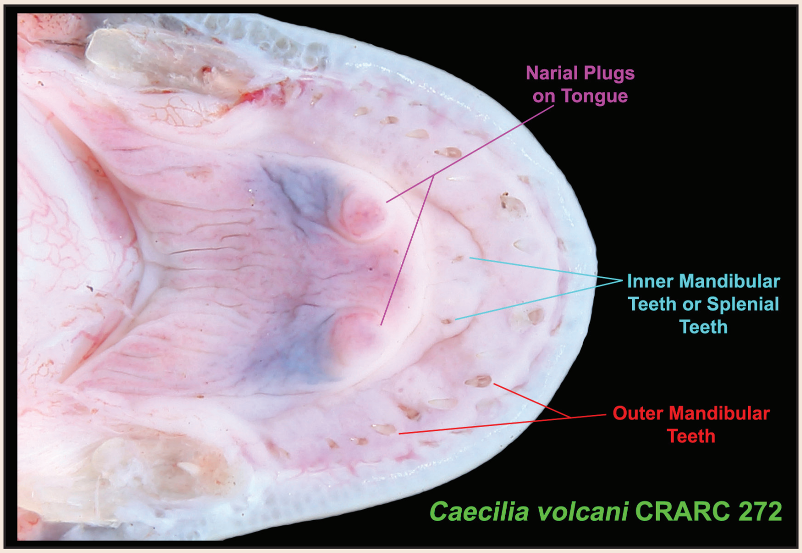

Fig. 5. View of the presence and position of the two inner mandibular teeth on the specimen of *Caecilia volcani* (CRARC 0272) from Guayacán de Siquirres, Provincia de Limón, Costa Rica. 📷 © Brian Kubicki

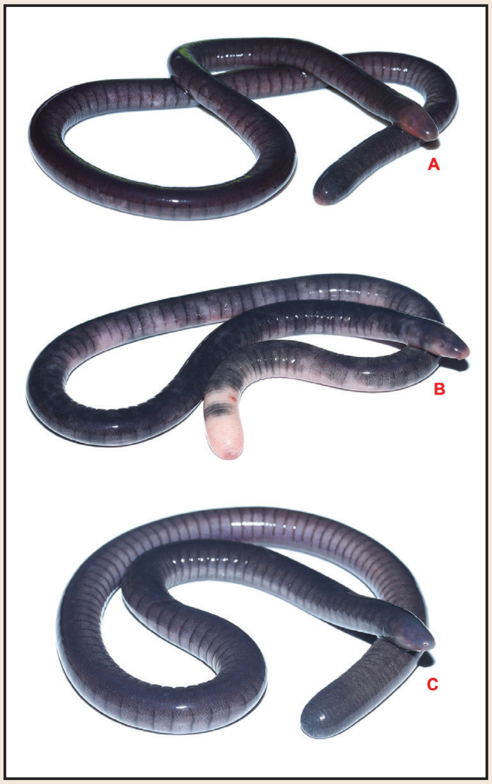

Fig. 6. Examples of chromatic variation in the head and body of three *Caecilia volcani* found at the Costa Rican Amphibian Research Center's Guayacán Rainforest Reserve, Guayacán de Siquirres, Provincia de Limón, Costa Rica. (A) = CRARC 0272; (B) and (C) = photographs of individuals released after the images were taken.

📷 © Brian Kubicki

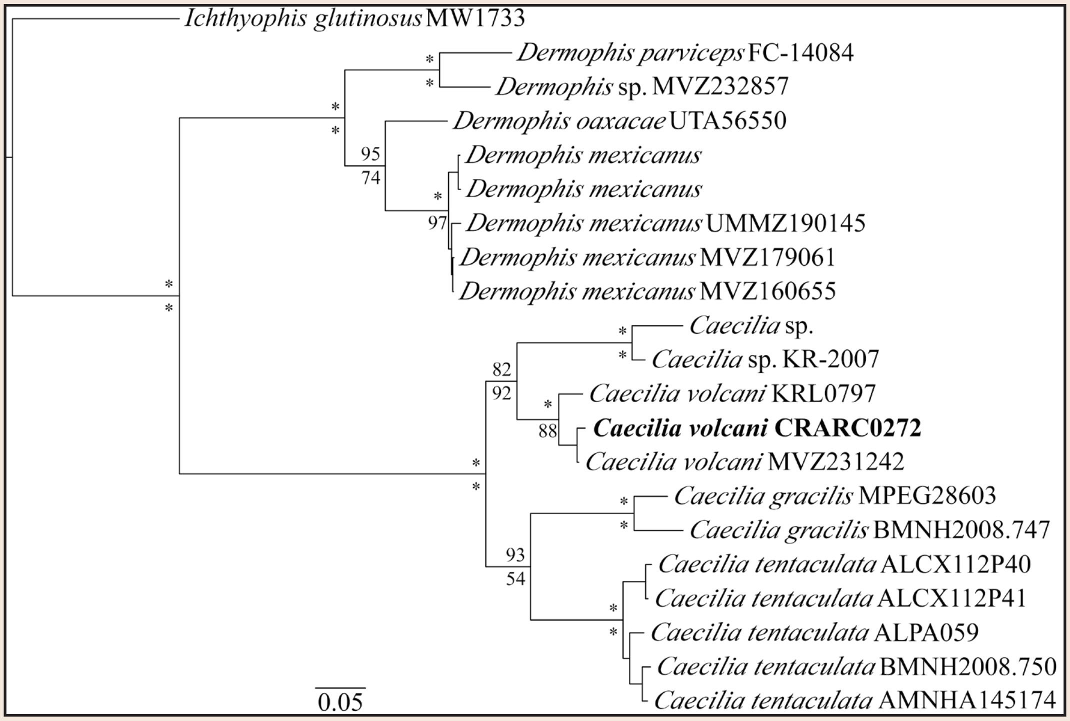

Fig. 7. Bayesian phylogenetic inference of the relationship of the Costa Rican specimen of *Caecilia volcani* (CRARC 0272) among members of the genera *Dermophis* and *Caecilia* for which 16S and cyt *b* mitochondrial DNA genes sequences are available on GenBank. Bayesian posterior probabilities (multiplied by 100) are shown above the branch; maximum likelihood bootstrap values from the RAxML analysis are shown below the branches. The scale bar refers to the estimated substitutions per site. The support values of any node within the species are not shown. The asterisks represent a support of 100.

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