New approach to old vertebrae – a morphometric comparison of Miocene and extant snakes

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Comparative morphological study of fossil and recent snakes is of key interest for taxonomic identification, paleobiological reconstructions and character evolution analyses.
Snake fossil record is sparse, due to the low occurrence of fossilisation of delicate bone structures, especially in smaller species. The characters used in study of extant snake vertebrae are most often degraded in fossils – protruding structures or exposed surfaces get eroded or broken off.

Fossil trunk vertebrae of *Natrix* sp. in different states of preservation

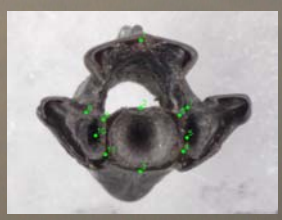
In this study, we applied the methods of geometric morphometrics to characterize shape variation of snake trunk vertebrae and explored bone structures less prone to damage. Landmarks were acquired from structures located near the centrum and at the base of the neural arch; we expected this approach to allow inclusion of larger number of fossil specimens, which could not be studied by the classical approach.

Trunk vertebrae of extant *Vipera* sp.

❑ Fossil material: snake vertebrae from a rich mid-Miocene assemblage (approx. 12Ma, European Land Mammal Zone MN 7/8) at Vračević locality, in the vicinity of Belgrade, Serbia.
❑ The sample of undistorted fossil trunk vertebrae in good condition, referred to genera *Natrix, Vipera* and *Elaphe,* was compared to extant snake vertebrae from corresponding recent genera.

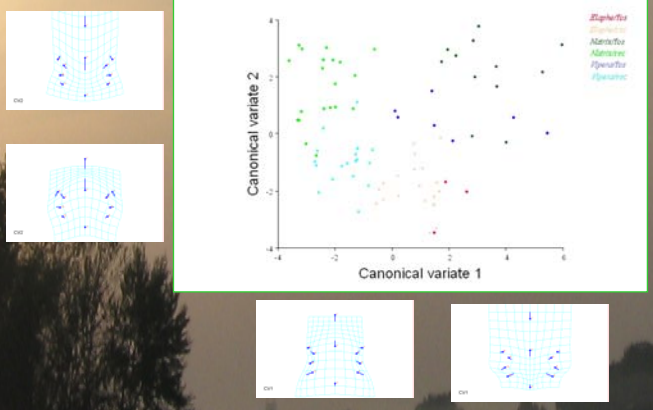
❑ Three axial and four pairs of lateral landmarks (11 landmarks in total) have been identified on the specimens and used for 2D geometric morphometric analysis. Bilateral acquisition addressed the problem of taphonomic deformation. Symmetric component of shape variation was used for the comparison of fossil vertebrae with extant samples.

Landmarks:
1) midline dorsal margin of zygosphaene
2) midline dorsal margin of centrum
3) midline ventral margin of centrum
4) and 11) contact of synapophysis with centrum
5) and 10) subcentral foramen
6) and 9) contact between neural arch and centrum
7) and 8) contact between neural arch and prezygapophysis

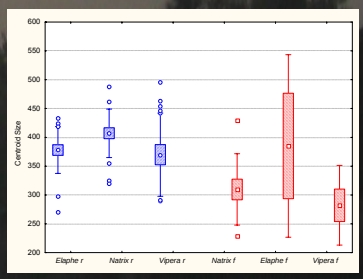


Fossil trunk vertebra of *Elaphe* sp. with landmarks

Fossil trunk vertebra of *Vipera* sp. with landmarks.

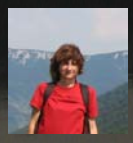


Canonical variate analysis (CVA) of overall shape differences in trunk vertebrae of fossil (fos) and recent (rec) snakes with deformation grids along the first and the second CV axis



Plot of centroid size (CS) means, standard errors and standard deviations for the analyzed fossil (red) and extant (blue) samples of snake vertebrae

➢ Fossil specimens had lower mean centroid size (CS), and higher variation in CS compared to recent ones. The range of fossil CS values was larger than the recent, mainly due to the *Elaphe* sample; the smallest and the largest vertebrae were fossil specimens. Principal component analysis showed that the highest variation in shape was associated with centrum/neural arch relative height ratio.
➢ Canonical variate analysis (CVA) was used to visualize the separation of vertebra shapes among analysed groups. The first two CV's explained 70.6% (CV1=42.2% and CV2=28.4%, respectively) of the total variance.
➢ Although the results show that this approach is promissing and the chosen landmarks are informative in case of typically damaged fossil snake vertebrae, more comprehensive sampling is needed to rigorously evaluate this approach.



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Research funded by Ministry of Education and Science, Republic of Serbia (grant no. 173025).