Ontogeny and habitat change in Mesozoic cephalopods revealed by stable isotopes ($\delta^{18}O$, $\delta^{13}C$)

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Knowledge of the life cycles, ecology and ontogeny of fossil cephalopods and especially of ammonoids is still poor. While ammonoids are frequently found in Paleozoic and Mesozoic marine sediments worldwide from the tropic-subtropic via boreal to antarctic-arctic zones, information on their habitat and ecology is scarce and imprecise. Their habitat is suggested to be the epi- and meso-pelagic zones. Fractionation and isotopic composition in oxygen and carbon isotopes ($^{16}O/^{18}O$ and $^{12}C/^{13}C$) refers to a change in stable isotope ratios, reflecting chemical and/or physical processes. Early studies of mollusc shells in respect to stable isotope composition ($\delta^{18}O$ and $\delta^{13}C$) already demonstrated that the isotope composition of carbonate shells is a function of seawater temperature. Since then, an enormous body of literature has used stable isotopes of bivalve and gastropod shells as environmental proxies. Isotope thermometry obtained by analyzing hard parts of cephalopods offers valuable information about paleo- and recent seawater temperatures as well.

The comparison of Recent *Spirula*, *Sepia*, and *Nautilus* allows quite different modes of life to be deciphered based on stable isotope signatures. Applying these methods to Mesozoic ammonoids might shed light on the strategies and environmental requirements of fossil cephalopods. One of the main objectives of the present study is to determine possible ontogenetic migrations in the water column in fossil cephalopod groups based on a comparison with stable isotope data from Recent cephalopods.

Stable isotope ($\delta^{18}O$ and $\delta^{13}C$) ratios were measured in successive aragonitic shell sequences of ammonoids (class Cephalopoda) to determine whether their depth distributions changed within ontogeny and whether stable isotope values differ in various morphological groups (e.g., Leiostraca vs. Trachyostraca). We concentrate mainly on $\delta^{18}O$ for temperature results and added $\delta^{13}C$ data to obtain informations on the ontogenetic history, for which full spiral measurements were undertaken for the first time. To obtain valid stable isotope data from ammonoid shells, we measured ontogenetic sequences (full shell) within different genera. Data sets from the Jurassic (*Cadoceras*) and Cretaceous (*Hypacanthoplite*s, *Nowakites*) were chosen due to the pure primary aragonitic shell preservation. The study was designed to extract better information on the habitat and life cycle of fossil cephalopods (e.g., ammonoids) in comparison with recent cephalopods (e.g., *Nautilus*, *Spirula*, *Sepia*) possessing equivalent or comparable hard parts. The data from three genera suggest different modes of life in at least two morphological groups.

We detected and established two main groups with different ontogenetic strategy based on the $\delta^{18}O$ data. The *wcw*-type (warm-cool-warm type) of *Cadoceras* resembles strategies in *Nautilus* and *Sepia*, which migrate from shallow into deeper environments and back in ontogeny (*wc-type*, warm-cool- type), and the *cw-type* (cool-warm type) of *Hypacanthoplites* resembling the first two migration phases of *Spirula* (*cwc-type*), which migrates from deeper into shallower and back again into deeper habitats. The main (three) phases revealed by both $\delta^{18}O$ and $\delta^{13}C$ data sets most probably reflect diet changes in juvenile to mid-aged individuals, followed by a habitat change for spawning adults. In *Cadoceras* the temperatures range from 21.2 °C for juveniles down to 12.1 °C for mid-aged individuals and back up 16.9 °C in adults. The *cw-type* strategy of *Hypacanthoplites* involves a temperature range of 22.8 °C to 28.9 °C. The respective mean values are 24.2 °C (juveniles), 25.8 °C (middle phase) and 27.8 °C (adults).

The $\delta^{13}C$ values also revealed three ontogenetic stages in *Cadoceras* and *Hypacanthoplites*, including two major shifts from positive to negative and from negative to positive values, which probably correspond to sexual maturation, the initiation of reproduction, and concomitant changes in diet. The presented data, combined with previous ontogenetic studies (e.g., stable isotopes) on *Spirula*, *Nautilus* and *Sepia* can be used as proxies to directly correlate the habitats and ontogeny of recent and fossil cephalopods.

Geochemische Untersuchungen an ostalpinen Kupfervorkommen und ihre Nutzung in prähistorischer Zeit

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Die Kupfererze der Ostalpen - insbesondere die Fahlerz- und Kupferkiesvorkommen - wurden in prähistorischer Zeit intensiv abgebaut, die Erze verhüttet und die gewonnenen Metalle weiträumig verteilt bzw. verhandelt. Für die archäometallurgische Forschung von besonderer Bedeutung sind in diesem Zusammenhang die Initial- und Aufbauphase der Kupfermetallurgie im ausgehenden Neolithikum und in der Frühbronzezeit sowie die Kupferproduktion in der mittleren und späten Bronzezeit, die vergleichsweise schon „industrielle“ Ausmaße erreichte.

Neben absichtlich zulegierten Metallen - vor allem Zinn - enthalten prähistorische Metallfunde meist eine Reihe von weiteren Bestandteilen, die aus dem Erz stammen und bei der Verhüttung zusammen mit Kupfer reduziert werden. Anhand dieser „Verunreinigungen“ wird versucht, Kupfersorten zu klassifizieren und deren chemischen „Fingerabdruck“ mit Erzlagerstätten zu vergleichen. Um die in vorgeschichtlicher Zeit genutzten Metallsorten regional zuordnen zu können, ist daher eine geologisch-lagerstättenkundliche Untersuchung der Erzvorkommen