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This is a pre print version of the following article:

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1794276> since 2021-07-18T15:56:35Z

Published version:

DOI:10.1016/j.ejca.2021.03.041

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A lost Tethyan evaporitic basin — Evidence from Cretaceous hemi-pelagic meta-selenite in the Eastern Mediterranean realm

Journal:	<i>Sedimentology</i>
Manuscript ID	Draft
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	n/a
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Keywords:	Evaporites, Blueschist Metamorphism, Sedimentology, Depositional Environment, Pseudomorphism, Neotethys

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**A lost Tethyan evaporitic basin — Evidence from Cretaceous hemi-
pelagic meta-selenite in the Eastern Mediterranean realm**

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ABSTRACT

Ancient evaporite deposits are geological archives of depositional environments characterized by a long-term negative precipitation balance and bear evidence for global ocean element mass balance calculations. Here, Cretaceous selenite pseudomorphs from western Anatolia ('Rosetta Marble')—characterized by their exceptionally morphological preservation—and their 'marine' geochemical signatures are described and interpreted in a process-oriented context. These rocks recorded Late Cretaceous high-pressure/low-temperature, subduction-related metamorphism with peak conditions of 1.0–1.2 GPa and 300–400°C. Meter-scale, rock-forming radiating rods, now present as fibrous calcite marble, clearly point to selenitic gypsum as the precursor mineral. Stratigraphic successions are recorded along a reconstructed proximal-to-distal transect. The cyclical alternation of selenite beds and radiolarian ribbon-bedded cherts in the distal portions are interpreted as a two type-of-seawater system. During arid intervals, shallow marine brines cascaded downwards into basinal settings and induced precipitation. During more humid times, upwelling-induced radiolarian blooms caused the deposition of radiolarite facies. Interestingly, there is no comparable depositional setting known from the Cenozoic world. Meta-selenite geochemical data ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$ values and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios) plot within the range of reconstructed middle Cretaceous sea water signatures. Possible sources for the ^{13}C -enriched (mean 2.2‰) values include methanogenesis, gas hydrates, and cold seeps fluid exhalation. Spatially resolved component-specific analysis of a rock slab display isotopic variances between meta-selenite crystals (mean: $\delta^{13}\text{C}$ 2.2‰; $\delta^{18}\text{O}$ -0.7‰) and host matrix (mean: $\delta^{13}\text{C}$ 1.3‰; $\delta^{18}\text{O}$ -2‰). The Cretaceous evaporite-pseudomorphs of Anatolia represent a basin wide event coeval with the Aptian evaporites of the Proto-Atlantic and shares many attributes, including lateral distribution of 600km and stratigraphic thickness of 1.5–2km, with the evaporites formed during the younger Messinian salinity crisis. The Rosetta Marble of Anatolia may represent the best-preserved selenite pseudomorphs worldwide and have a clear potential to act as template for the study of meta-selenite in deep time.

Keywords Evaporites, Blueschist Metamorphism, Sedimentology, Depositional Environment, Pseudomorphism, Neotethys

60 INTRODUCTION

61 Sedimentary rocks are exploited by means of proxy data that serve both for hindcasting purposes but
62 also provide fundamentally important input parameters for climate models (e.g. Veizer *et al.*, 1999;
63 Fleitmann *et al.*, 2004; Della Porta, 2015; Immenhauser *et al.*, 2016). With reference to sediments
64 and sedimentary rocks in oceanic basins, work performed in the context of ocean drilling has added
65 significantly to our understanding of Earth’s history, the evolution of life, and past climate dynamics
66 (e.g. Zachos *et al.*, 2001; Miall, 2013). This becomes particularly important when dealing with earth’s
67 deep time record that, in many cases, has seen variable degrees of diagenetic to metamorphic
68 overprint. Deep burial and subsequent uplift or folding and thrusting in mountain belts affect
69 sedimentary rocks and commonly alter their petrographic, mineralogical, or geochemical signatures
70 (e.g. Schneider *et al.*, 2008; Swart, 2015).

71 Evaporites are peculiar amongst earth’s sedimentary archives as they represent a rather
72 unique depositional environment. The nucleation of evaporite minerals and their morphologies is
73 directly influenced by environmental parameters such as salinity, temperature, and availability of
74 organic matter (e.g. Cody & Cody, 1988; Ortí, 2011; Aquilano *et al.*, 2016; Warren, 2016). Further,
75 evaporitic minerals have the potential to preserve the trace element distribution, fluid inclusion
76 composition, and isotope ratios of brines from which they precipitated (e.g. Deer *et al.*, 1992; Lu *et al.*,
77 2001, 2002; Natalicchio *et al.*, 2014; Warren, 2016), and, therefore, they represent an important
78 archive for paleoenvironmental reconstructions (Warren, 1999). Nevertheless, evaporites are prone
79 to dissolution, which may result in a preservation bias in the geological record. The authors here
80 argued that the potential of meta-evaporites and their pseudomorphs as archives in the deep-time
81 geological record has been hampered by a dearth of dedicated studies. To address this, the present
82 paper explores the potential of metamorphosed Cretaceous evaporitic successions in Turkey. Meta-
83 evaporites and related meta-sedimentary rocks, now present as marble fabrics and cherts, are
84 regionally referred to as “Rosetta Marble”, a casual catch-it-all-term that is applied throughout this
85 paper. Previous studies (Scheffler *et al.*, 2014, 2016) established the fundamental stratigraphic
86 distribution, lithological associations, primary versus metamorphic mineralogies, and metamorphic
87 pressure–temperature (P–T) evolution of the Rosetta Marble deposits and the reader is referred to
88 these sources for details.

89 Building on previous work, this paper takes the next step and places these findings in a
90 conceptual and process-oriented context by documenting macro- and mesoscopic sedimentary and
91 stratigraphic features of the Rosetta meta-evaporites. This includes the distribution of different
92 meta-selenite morphotypes in their respective depositional environments based on a conceptual
93 model from proximal-to-distal settings. Subsequently, the Rosetta Marble deposits are compared

with non-metamorphosed analogue facies from the Middle (Badenian) and Late (Messinian) Miocene evaporite deposits of the Paratethys and the Mediterranean basins, respectively. Finally, light stable and radiogenic isotope data ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$, $^{87}\text{Sr}/^{86}\text{Sr}$) are combined with petrographic observations to assess the diagenetic pathways of these rocks and their corresponding proxy data from deposition via subduction to exhumation. The data shown here highlight the potential of Cretaceous meta-evaporites—conventionally not considered as suitable palaeoenvironmental archives due to their high degree of recrystallization—when placed in their paleoenvironmental context and direct implications for the Neotethyan palaeogeography and tectonic evolution of the Eastern Mediterranean are proposed. Beyond that, this paper is of clear generic importance for those interested in deep time archive research in general and has significance for reconstructions of seawater salinity over geological time.

PLATE TECTONIC SETTING, REGIONAL TECTONOSTRATIGRAPHIC FRAMEWORK, AND STUDY SITES

The Anatolian microplate formed due to the collision of several microcontinents during the closure of the Tethyan realm (e.g. Celâl & Yilmaz, 1981; Okay *et al.*, 1986; Şengör, 1990). Whereas northern Anatolia is composed of Eurasia-derived units, the domains south of the Izmir–Ankara Suture Zone were derived from Gondwana, such as the Anatolide–Tauride Block (Fig. 1). The passive margin of this former microcontinent is represented by the metamorphic Ören–Afyon Zone and the thrust-and-folded, low-grade to non-metamorphosed Tauride Platform (Fig. 1). The Ören–Afyon Zone and Tauride Platform present a continuous Mesozoic stratigraphic sequence of Lower Triassic siliciclastic rocks to Middle Triassic to Upper Cretaceous carbonaceous (marine) sediments deposited in neritic to pelagic environments (e.g. Gutnic *et al.*, 1979; Candan *et al.*, 2005). The transition from neritic to pelagic deposition was constrained paleontologically to Valanginian–Aptian times (Özcan *et al.*, 1988, 1989, 1990; Göncüoğlu, 2011). The uppermost pelagic carbonate formation correlates lithostratigraphically to the Cenomanian–Maastrichtian (Özcan *et al.*, 1989; Göncüoğlu *et al.*, 1992; Candan *et al.*, 2005; Cohen *et al.*, 2013). During the latest Cretaceous, the Ören–Afyon Zone were overlain by olistostromal formations and serpentinite mélanges (de Graciansky, 1972; Robertson & Ustaömer, 2009) and subducted (Pourteau *et al.*, 2013). In this process, the Ören–Afyon Zone reached maximum metamorphism at around 70 Ma, coevally with ophiolite obduction onto the Tauride Platform (Collins & Robertson, 1997; Pourteau *et al.*, 2016). From the Eocene to the Miocene, the westernmost extension of the Ören–Afyon Zone (Ören Unit) was transported southwards over the uplifting Menderes Massif (Güngör & Erdoğan, 2001; Rimmelé *et al.*, 2003, 2006; van Hinsbergen *et al.*, 2010; Pourteau *et al.*, 2013). Former evaporite relicts within the pelagic carbonate formations are distributed widely in the Anatolide–Tauride Block (Scheffler *et al.*, 2016).

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128 The present study focuses on the neritic to pelagic carbonate sequence (the “Rosetta Marble”) of the
129 Ören Unit, which crops out near the villages of Fesleğen, Akçakaya, and Karaböğürtlen
130 (supplementary Fig. A).

132 **CASE SETTING: THE ROSETTA MARBLE**

133 Below we provide a condensed review of previous work that is relevant to the reader of this paper.
134 Please consider cited work for details. This paper refers to what has been addressed as the ‘Rosetta
135 Marble’ by Rimmelé *et al.* (2003), i.e. calcitic marble exhibiting three-dimensional, fan-shaped
136 morphologies resembling typical selenite megacrystals (Scheffler *et al.*, 2014, 2016). Rosetta Marble
137 in Cretaceous strata are restricted to the Ören–Afyon Zone (Fig. 1), in which they form part of the
138 upper Mesozoic hemi-pelagic sequence composed of marble–chert couplets. Analogues to this meta-
139 evaporite are lacking in portions of the Tauride platform that have not been metamorphosed to an
140 equal degree. So far, the sedimentary information archived in Rosetta Marble stratigraphic unit have
141 been underappreciated. Previous detailed stratigraphic studies did not refer to the abundant, meter-
142 sized crystal splays (Brunn *et al.*, 1970; Bernoulli *et al.*, 1974; Brinkmann, 1967; Poisson, 1977, 1984;
143 Gutnic *et al.*, 1979; Özkaya, 1990; Özer *et al.*, 2001). Candan *et al.* (2005), Rimmelé *et al.* (2005),
144 Oberhänsli *et al.* (2010), and Pourteau *et al.* (2010) described Rosetta Marble horizons and applied
145 them as markers for stratigraphic correlation in the frame of regional tectonic reconstructions.
146 Morphological attributes of calcitic Rosetta Marble crystals, revealing important similarities with
147 selenite crystals, were described by Scheffler *et al.* (2014, 2016). Imprints of minerals with typical
148 selenite morphologies in formerly soft, siliceous layers document the syn-depositional nature of
149 these minerals. Based on arguments including crystal morphologies and paleo-depositional
150 information, it is postulated that the Rosetta Marble represents pseudomorphs after selenite gypsum
151 forming cm- to m-sized, three-dimensional fans (Scheffler *et al.*, 2014, 2016). The authors inferred
152 that selenite transformed to aragonite during early diagenesis and subsequent subduction, and
153 aragonite was replaced by calcite during exhumation. In contrast, evidence that these radiating
154 calcite rods represent former aragonitic mega-botryoides nucleating and precipitating on the
155 seafloor is lacking altogether.

156 The Rosetta Marble deposits of the Ören Unit have been subjected to high-pressure/low-
157 temperature (HP/LT), i.e. subduction-related metamorphism, as evidenced by (i) high Sr contents
158 measured in fibrous calcite, which represent pseudomorphs after aragonite fibers (Rimmelé *et al.*,
159 2003), (ii) aragonite inclusions in quartz (Scheffler *et al.*, 2016), (iii) *P–T* estimates for pelitic layers
160 enclosing the Rosetta Marble deposits (Scheffler *et al.*, 2016), and (iv) *P–T* estimates for adjacent

formations (Oberhänsli *et al.*, 2001, Rimmelé *et al.*, 2003, 2005; Pourteau *et al.*, 2014). Peak P – T conditions were estimated as 1.0–1.2 GPa and 300–400°C (Fig. 2). Following Gillet & Goffé (1988), the overall lack of aragonite indicates that it was replaced by calcite above 200°C, i.e. at pressures >0.5 GPa (Fig. 2). No pseudomorphs after anhydrite were found in the Rosetta Marble units. The gypsum-to-carbonate transformation therefore took place before pressure–temperature conditions of stable anhydrite were reached. The replacement of gypsum by carbonate can be either induced by bacterial sulphate reduction or by thermochemical sulphate reduction (e.g. Machel, 2001). With reference to thermochemical sulphate reduction, thermodynamically stable conditions allow for gypsum to directly transform to aragonite along a subduction-type geothermal gradient (<160°C/GPa; Fig. 2). Moreover, thermochemical sulphate reduction allows the preservation of former evaporite morphologies as opposed to bacterial sulphate reduction that is usually attributed to fabric-destructive alteration (Fernández-Díaz *et al.*, 2009). Additional evidence for thermochemical sulphate reduction as main mechanism transforming selenite to carbonate comes from the elevated Sr concentrations in calcite fibers (>3500 ppm) agreeing with an aragonitic replacement of selenite (Scheffler *et al.*, 2016). Cathodoluminescence imaging of pseudo-hexagonal meta-gypsum crystals shows generally concentric zonation reflecting trace element variations from core to rim. Although gypsum was transformed into aragonite that was in turn pseudomorphed into calcite, a primary zoning of gypsum is preserved and suggests a relative immobility of the trace elements during metamorphism and neomorphism (Scheffler *et al.*, 2016).

MATERIALS AND METHODS

Field work and sample material

Extensive fieldwork was performed in the Ören Unit, south-west Turkey. Structural and stratigraphic data were collected along three measured sections. Particular care in sampling was taken to avoid a stratigraphic bias induced by faults and folds. Criteria to establish the lithostratigraphic orientation of strata in three dimensions included erosional surfaces, fluid-escape structures, and characteristic growth textures of evaporites. Rock samples of meta-carbonate, meta-sandstone, and meta-chert were collected and processed for petrographic examination (thin sections) and geochemical analysis.

Optical analyses

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32 polished thin section were investigated with optical polarization microscopes at Potsdam University (Leica DMRXP) and Friedrich-Schiller-University Jena, both Germany (AXIO Zeiss Imager.M2m, AudioCam MRcS Zeiss). The HC6-LM Cathodoluminescence microscope at Potsdam University was used at 14 kV with a beam current of 0.2 mA and an operating vacuum of $5 \cdot 10^{-4}$ mbar. A coupled polarized light microscope allows for navigation and documentation. Samples were carbon coated to avoid electrical charging. Cathodoluminescence images were used to choose appropriate minerals for isotope analysis, because altered and primary areas can be distinguished.

Geochemical analyses

184 rock powders for isotope analysis were produced by using a low-speed micro-drill equipped with diamond-studded drilling heads. Homogeneous sample sides were drilled on freshly cut and cleaned rock slabs. Micro-drilled carbonate powders were analyzed for their carbon ($\delta^{13}\text{C}$) and oxygen ($\delta^{18}\text{O}$) isotopic values using a Thermo Fisher Scientific Gasbench II carbonate device coupled to a Thermo Fisher Scientific Delta S Isotope Ratio Mass Spectrometer at Ruhr-University, Bochum, Germany. Isotopic values were standardized to V-PDB. See Christ *et al.* (2012) for details on lab-specific analytical procedures. The uncertainty on the plotted values is equal or smaller than 0.06‰ for $\delta^{13}\text{C}$ and 0.1‰ for $\delta^{18}\text{O}$. Strontium isotopes ($^{87}\text{Sr}/^{86}\text{Sr}$) were analyzed using a Finnigan MAT 262 thermal-ionisation mass spectrometer (TIMS) at Ruhr-University Bochum, Germany. $^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: NBS 987 value McArthur and NBS 987 Bochum mean value. Refer to Geske *et al.* (2012) for lab-specific analytical details. The maximal error for $^{87}\text{Sr}/^{86}\text{Sr}$ is $\pm 2\sigma_{\text{mean}} = 0.000008$. Stable and radiogenic isotope analytical results are given in the supplementary material.

DATA PRESENTATION

Stratigraphy and Sedimentology

Two types of end member facies were identified. One is build up by grayish, thickly bedded (up to 2 m) marble successions with intercalated calcareous quartzite (medium to coarse grained meta-sandstone) beds and occasional whitish to grayish aligned nodular and ribbon bedded chert (Fig. 3A; type locality Fesleßen: N 37°03.396'' E 27°47.457''). Meta-sandstones locally display fine lamination, a fining-upward trend and they are occasionally overlying an irregular erosional surface. All of these attributes suggest a turbiditic origin of these beds. The other end member facies is present in the form of reddish, thinly bedded (cm's to a few dm's) marble-chert alterations, intercalated with thin

224 radiolarian-bearing meta-wackestones (Fig. 3C; type locality Karaböğürtlen: N 37°04.388'' E
225 28°34.081''). Intermediate types include grayish marble beds (several dm's thick) alternating with
226 whitish cherty beds and nodules (Fig. 3B; type locality Akçakaya: N 37°04.588'' E 27°51.042'';
227 supplementary Fig. A).

228 Three sections representing the three Rosetta Marble facies associations (type localities)
229 were sampled for O, C, and $^{87}\text{Sr}/^{86}\text{Sr}$ isotope analysis: The Fesleğen, the Karaböğürtlen, and the
230 Akçakaya sections. The Fesleğen section consists of thickly bedded marble beds, rarely intercalated
231 with chert layers and nodules (Fig. 4 and supplementary Fig. C). In the stratigraphically lowermost
232 part, calcareous-sandy turbiditic horizons are common features. The marble layers are mainly
233 composed by fans of large selenite-pseudomorphs. Occasionally, these fans are embedded in a dark
234 grey marble matrix. The upper part of the section contrasts with the lower intervals and is mainly
235 built by a regular alternation of marble beds bearing gypsum-pseudomorphs and a few cm-thick
236 chert layers. The Karaböğürtlen section show two intervals characterized by their different facies
237 associations. The lower one is composed of rather uniform thickly to moderately bedded meta-
238 selenite–chert alternations (Fig. 5A, D and supplementary Fig. D). The frequency of chert beds
239 increases upsection and their thickness decreases. The upper interval of the section consists of a
240 reddish, thinly bedded marble-chert alternation (Fig. 5A, B and E). Chert ribbons are in part
241 embedded in a host facies of meta-wackestones rich in radiolaria tests. The third section, located
242 near the village of Akçakaya, shows a facies pattern that is intermediate between the Karaböğürtlen
243 and Fesleğen endmember sections. Based on its structural position, the Akçakaya section is most
244 likely stratigraphically older than the Fesleğen section. These rocks consist of very regular thickly to
245 medium thickly bedded selenite-pseudomorph bearing marble-chert alternations but they are devoid
246 of the turbiditic meta-sandstones typical for the Fesleğen locality. Generally, these units are
247 lithological homogeneous in their appearance relative to the more diverse other sections
248 (supplementary Fig. E).

249

250 **Morphological features and growth orientation of meta-selenites**

251 Meta-selenite textures display a variety of systematic morphotypes (growth forms and crystal habit).
252 The most common ones are described in the following (Figs 6 to 8).

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254 *Selenite growth orientation*

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Four main growth orientations of selenite pseudomorphs, relative to the bedding plane, are recognized: (i) upward growth (Fig. 6A and B); (ii) downward growth (Fig. 6C), (iii) up- and downward growth (Fig. 6D, E and F), and (iv) horizontal/in-plane orientation (Fig. 7A and B).

Upward growing meta-selenites ('Rosettas') are predominantly fan or dome shaped (Fig. 6A). Tilted crystal fans (subparallel to the bedding plane) are frequently observed (Fig. 6B). Downward growing meta-selenite fans/domes (Fig. 6C) are uncommon. Up- and downward oriented fans are comparable in size and symmetrical. The nucleation points are aligned with chert-ribbons and – nodules (Fig. 6A-D); often, the top of a lower crystal fan serves as nucleation for the next crystal dome (Fig. 6A) or they grow from impurity-rich surfaces (Fig. 6E). Selenite fans growing from a nucleation point devoid of silica are restricted by top and bottom chert/marble-layers (Fig. 6F).

Amongst the horizontally growing (in-plane) Rosetta fans (Fig. 7), three subtypes can be identified: (i) Radial Rosettas with long crystal rods radiating from a central nucleation site; (ii) flower-like Rosettas showing basal sections of crystals in the centers of the radiating fans. Small rods radiate away and gradually change to longer crystals with increasing distance to the center; and (iii) concentric Rosettas. Here, long rods start radiating from a certain distance to the rod-free center. The diameters of individual fans are remarkable and may reach 3 m. The length of individual meta-selenite crystals within fans range from a few cm's to 1.5 m's (Fig. 7A). Where fans compete for space, typical features of converging crystallization fronts are observed (Fig. 7B). Where fans are spatially separated, crystals grow idiomorphic and form mega-crystals.

Selenite crystal habits and morphotypes

The most common morphotypes and crystal habits of selenite pseudomorphs are cm- to meter-long, straight to curved-radiating rods composed of calcite crystals (morphotype i, Fig. 7). Many marble layers are mostly made up of calcite Rosettas with only limited amounts of fine-grained matrix (Fig. 7). Locally, calcite rods are embedded in a fine-crystalline homogeneous dark grey marble matrix (Fig. 8A). A thin layer of marly-quartzitic sediment often fringes individual calcite rods (Fig. 8A, Scheffler *et al.*, 2016). Less common morphotypes are: (ii) stacked swallowtail crystals (Fig. 8B), (iii) fishbone-like crystals, restricted to coarse-grained sandy levels (Fig. 8C), (iv) Christmas-tree shaped selenites pseudomorphs similar to dendritic habits (Fig. 8D), (v) flower-like arranged curved sabre crystals (Fig. 8E), and (iv) crystals forming palisade layers (Fig. 8F).

286 *Petrography and mineralogy: microscale crystal habits and their relation to matrix and meta-*
287 *radiolarites*

288 The selenite pseudomorphs are composed of fibrous calcite that in turn is a pseudomorph after
289 aragonite. The material that often fringes individual meta-selenite crystals comprises microcrystalline
290 quartz, dolomite rhombs, mica, and opaque accessory phases (Fig. 9A and B). Monoclinic crystals
291 habits (former gypsum) are visible in the case of small (mm-scale) rods floating in matrix meta-
292 sediments (Fig. 9A to D). Crystal habits resemble elongated rods or pseudo-hexagonal sections
293 (perpendicular to the c-axes of the rods) with crystallographic angles typical for gypsum (Buick &
294 Dunlop, 1990; Fig. 9D). Within the pseudo-hexagonal crystal outlines calcitic pseudomorphs after
295 aragonite fibers are mostly well preserved (Fig. 9E). The contact between meta-selenite marble and
296 chert layers is usually distinct and rather abrupt (Figs 9F and 10A). Chert layers consist of a ribbon
297 bedded or nodular siliceous core and an increasingly dolomitic outer zone (Fig. 9F). Insoluble material
298 and minor calcite crystals increase in number towards the chert-rich center of individual beds (Fig.
299 10A). Raman spectroscopy indicates that dolomites were in part dedolomitized and are now calcitic
300 or dissolved. Some of these dedolomitized rhombs exhibit an internal zonation. Molds with a
301 rhombic habit are common on the weathered and fresh sample surfaces, most likely indicating
302 former dolomite crystals. Calcified relicts of radiolarian tests are present in meta-wackestone layers
303 (Fig. 10B) whereas microcrystalline silicified radiolarian tests are preserved within chert layers (Fig.
304 10C and D). The degree of preservation of altered radiolarian tests changes from locality to locality
305 and ranges from neomorphosed but morphologically well-preserved to barely recognizable.

306 Under cathodoluminescence imaging, different crystallization stages and fluid-related
307 alteration are recognized. Authigenic carbonate after gypsum appears in dark bluish-blackish
308 luminescence colors, whereas the surrounding, recrystallized fine-grained matrix displays orange
309 luminescence (Fig. 11). Under normal light microscopy, zoning of pseudohexagonal crystals is not
310 obvious. These crystals show, however, four, arguably primary and distinct cathodoluminescence
311 zones (Fig. 11A). This is considered remarkable when taking the complex metamorphic pathway of
312 these rocks into consideration.

313

314 **Geochemical data**

315 *Carbon and oxygen isotope data of selenite pseudomorphs and stratigraphic patterns in carbon*
316 *isotope signatures*

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317 Most of the bulk $\delta^{13}\text{C}$ values obtained from selenite pseudomorphs and their bulk sediments (*matrix*)
318 plot within the range of reconstructed mean mid-Cretaceous sea water DIC ($0.3 - 3.2 \delta^{13}\text{C}$) and even
319 the oxygen isotope data are only moderately depleted in ^{18}O (0 to $-3.1 \delta^{18}\text{O}$; Fig. 12, Veizer *et al.*,
320 1999). Carbon and oxygen isotope data show cluster that fit with their sampling sites and
321 stratigraphic levels (Fig. 12, Table 1). Although Bodrum samples are lacking selenite pseudomorphs,
322 they yield similar values as the other localities in which selenite pseudomorphs are observed.

323 The data serve to test if stratigraphic facies changes are detectable in their bulk geochemical
324 pattern. For details on the carbon, oxygen, and radiogenic strontium isotope data from all three
325 sections, refer to figures 5, 12, 13 and tables 1 and 2. Additional figures and extended data tables can
326 be found in the digital appendix. Below we briefly describe the isotope trends for each facies.

327 In the Fesleğen section, the transition from the lower (selenite bearing marble layers with
328 rare cherts and intercalated quartzite) to the upper (marble-chert couplets) section is well depicted
329 by the isotope pattern (supplementary Fig. C). Carbon bulk isotope values from the upper part of the
330 section yield slightly heavier values (mean: 2.2‰) than samples from the lower part of the section
331 (mean: 2.0‰ ; Table 1). In the Karaböğürtlen section, the upper part exhibits the most ^{13}C -enriched
332 carbon isotope (mean: 3.3‰) whereas the lower part is consistent with the majority of measured
333 samples (mean: 1.7‰ ; Fig. 5E, Table 1, supplementary Fig. D). The oxygen isotope values are lower in
334 the upper (mean: -2.7‰) than in the lower part of the section (mean: -1.3‰). Five samples from the
335 upper part of the section show the lowest oxygen isotope values (mean: -4.4‰ ; Figs 12 and 13). In
336 the Akçakaya section, C and O isotope values display an invariant pattern, mirroring the absence of
337 major lithological changes (Table 1). Nevertheless, carbon (mean: 1.3‰) and oxygen (mean: -2‰)
338 curves have their lows and highs at the same positions and hence display covariance (supplementary
339 Fig. E). $\delta^{13}\text{C}$ values of all three sections plotted in one diagram show an offset of 4‰ in the upper
340 portions (Fig. 13).

341 Although the $^{87}\text{Sr}/^{86}\text{Sr}$ isotope values in this study are limited, they show an interesting trend
342 similar to those of carbon (and oxygen) isotope values. In the Fesleğen section, $^{87}\text{Sr}/^{86}\text{Sr}$ isotope
343 ratios are slightly less radiogenic in the upper part of the section (mean: 0.707522) and more
344 radiogenic in the lower part (mean: 0.707551). In the upper red part of the Karaböğürtlen section the
345 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios continuously increase (mean: 0.7075578) with a peak value upsection, that coincide
346 with a color change to yellow (Fig. 5E, Table 2). In the lower portion, lower $^{87}\text{Sr}/^{86}\text{Sr}$ values are
347 measured (mean: 0.7074066). The Akçakaya section shows no chemostratigraphic variances in
348 $^{87}\text{Sr}/^{86}\text{Sr}$ isotope values (mean: 0.707368).

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350 *Spatial distribution of carbon and oxygen isotope values across a selenite-pseudomorph and its host*
351 *sediment*

352 A total of 36 samples for carbon and oxygen isotope analyses were drilled in a selenite-pseudomorph
353 rock slab (Fig. 14). Carbon isotopes within meta-selenite-crystals (i) are clearly enriched in ^{13}C (mean:
354 2.2‰), whereas the host sediment is depleted (mean: 1.7‰). The host sediment can be separated in
355 (ii) matrix, (iii) matrix with small meta-selenite crystals and (iv) rod-fringing material. The matrix
356 *sensu stricto* exhibits the lowest $\delta^{13}\text{C}$ values (mean: 1.3‰). Although $\delta^{18}\text{O}$ isotopes in metamorphic
357 rocks are potentially strongly overprinted, a purely descriptive subdivision of different clusters of
358 isotope data becomes obvious: (i) selenite-pseudomorphs (mean: -0.7‰), (ii) matrix (mean: -2‰),
359 (iii) matrix with small meta-selenite crystals (mean: -1.2) and (iv) rod-fringing material (mean: -0.2‰;
360 supplementary figures F and G).

361

362 INTERPRETATION AND DISCUSSION

363

364 Sections studied in the bathymetric context of a lost Cretaceous evaporitic basin

365 Morphological features evidencing former selenite mega-crystals were reported from Rosetta Marble
366 localities across the 400-km-long Ören–Afyon Zone (Scheffler *et al.*, 2016). The widespread
367 distribution of these peculiar stratigraphic intervals in the uppermost part of the Mesozoic carbonate
368 sequence, bears witness to a middle Cretaceous evaporitic basin, now mostly lost in a subduction
369 zone during Late Cretaceous to Early Paleocene times. Middle Aptian palaeogeographic
370 reconstructions of the Mediterranean area (Barrier & Vrielynck, 2008) depicted the Ören–Afyon Zone
371 as part of a deep-marine basin bordered to the south by extensive shallow-marine areas represented
372 by the shelf carbonate sequences of the Tauride Platform. Remnants of the evaporitic, turbiditic, and
373 siliceous sedimentary cover of this basin (or these basins) are now exposed in the sections discussed
374 in the context of this paper. Acknowledging the considerable difficulties resulting from an attempt to
375 reconstruct a former basin based on incomplete, spatially separated sections that are only indirectly
376 dated by means of regional correlations (e.g. Özcan *et al.*, 1989; Göncüoğlu *et al.*, 1992; Candan *et*
377 *al.*, 2005), some tentative suggestions are made and their implications discussed. To reconstruct the
378 internal architecture of the evaporitic basin, the three studied stratigraphic successions are restored
379 along a proximal-to-distal transect (Fig. 15). The observed facies associations reflect slope to basinal
380 domains. Thick-bedded, graded sandstone is ascribed to the relatively proximal, i.e. base-of-slope

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environments, whereas radiolarite (now chert) are pelagic deposits and generally a predominant component of the most distal formations.

Meta-evaporites as such are not diagnostic of any specific bathymetric domain since evaporites precipitate from hypersaline water masses that may form on the shelf or in basins (Warren, 1999). Schmalz (1969) pointed out that the precipitation of evaporites in (marginal) basinal settings takes place where parental brines underlie waters of normal salinity. These dense fluids do not mix with marine surficial waters and sink to the floor of basins. Roveri *et al.* (2014) reported on recent Mediterranean high density fluids forming at shelf levels and cascade downwards to the basin center. These ‘Dense Shelf Water Cascading’ (DSWC) currents play an important role in shelf erosion and sub-marine canyon formation (Roveri *et al.*, 2014). Two high-salinity-water-producing scenarios are proposed: (i) silled shallow sub-basins that suffered periodically spillovers and subsequent desiccation forming hypersaline brines or (ii) cascading semi-dense waters that accumulate in deep marine basins and get to the oversaturation state down there. On the base of these considerations, Roveri *et al.* (2014) supported a deep-water–deep-basin-model (e.g. Schmalz, 1969; Hsü *et al.* (1973) ; Debenedetti, 1982) for the long standing debate on the formation of Messinian saline giant.

The lower part of the Fesleğen section comprises predominantly thickly bedded (proximal) turbidite intervals. This significant terrigenous influx is evidence that the lower Fesleğen section represents the most proximal (landward) environment among the Rosetta Marble sections studied here (Fig. 15). Upsection, the proportion of meta-selenite and then of meta-radiolarite increases, depicting an overall deepening upward trend or an increasing production of radiolarian tests potentially assigned to enhanced upwelling.

Thickly bedded marble–chert couplets, such as exposed in the upper Felseğen section, the Akçakaya section, and the lower Karaböğürtlen section, represent occasional turbidite deposition alternating with prolonged periods of hemi-pelagic radiolarite sedimentation and agree with a more distal depositional environment. Bedded hemi-pelagic carbonate successions exposed on the Bodrum Peninsula and in the Taurides lack intercalations of meta-selenite deposits. The reason for this is not entirely understood but might suggest a more open and better circulated environment that did not allow for evaporitic brines to assemble.

The Karaböğürtlen section (Figs 5 and 15) consists of thinly-bedded meta-radiolarite–meta-selenite couplets. Meta-wackestone layers fringing specific chert ribbons are common in the upper part of the section but absent in the lower part. The section is potentially indicative of a deepening-upward trend and may represent the most distal and most basinal setting of the transect studied.

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414 Interpretation of the selenite–radiolarite couplets

415 The cyclical alternation of large selenite crystals with beds of radiolarian cherts is uncommon in the
416 geological record (Warren, 1999) and requires discussion. The main problem lies in the fact that
417 radiolarian facies commonly indicates an open shelf or even a basinal depositional environment
418 whereas meter-scale selenite crystal formation is often typical of smaller marginal evaporitic settings
419 (e.g. Båbel, 1987; Ortí, 2011). When comparing the studied sections with the Messinian evaporites in
420 the Mediterranean realm, selenite nucleation and growth is restricted to silled, marginal basins with
421 bathymetries of not more than about 200 meters (Lugli *et al.*, 2010). No examples of meter-long
422 selenite crystals forming at these depths are known from the Cenozoic. Moreover, in bathymetric
423 ranges below the neritic domain (> 200 m), the formation of sulphate evaporites is likely inhibited by
424 high rates of bacterially-promoted sulphate reduction via degradation of organic matter (De Lange &
425 Krijgsman, 2010; Garcia-Veigas *et al.*, 2018).

426 In the most distal Rosetta Marble facies associations (upper Karaböğürtlen section; Fig. 15),
427 remarkably well-preserved radiolarian pseudomorphs in meta-chert and in radiolarian-rich meta-
428 wackestone might be indicative of a higher abundancy of radiolaria and of higher productivity. Other
429 factors such as overall lower sedimentation rates or differential pathways of silica diagenesis should
430 not be excluded at this state. Occasionally, radiolaria thrive in neritic water masses, mainly in the
431 context of upwelling systems (Nigrini & Caulet, 1992, and references therein) but the excellent
432 preservation of sedimentary structures in these sections suggests a bathymetric range beneath the
433 reach of storm waves (Immenhauser *et al.*, 2008), i.e., water depths in excess of 100–200 meters or a
434 shallower protected setting. The lack of fabric destructive bioturbation is perhaps best explained by
435 elevated porewater salinity.

436 Deposition and preservation of shallow-water, siliceous radiolaria facies require two
437 boundary conditions: (i) a radiolarian bloom in the surficial water masses, and (ii) the absence of
438 significant amount of detrital and carbonate influx to the site of deposition of the radiolarian facies.
439 It must be emphasized that the rocks studied are not radiolarian limestones but genuine radiolarian
440 cherts.

441 Two tentative depositional scenarios offer themselves that might explain the alternation of
442 chert-evaporite couplets (Fig. 15): (i) One scenario (the chert-turbiditic sandstone mode) reflecting
443 more humid conditions in the hinterland with active riverine transport of siliciclastic material through
444 turbidity currents in the more marginal setting. In more open shelf zones, upwelling of basinal water
445 might have triggered radiolarian blooms resulting in the deposition of siliceous deposits. The dilution
446 of coastal seawater by riverine influx combined with upwelling of normal marine seawater inhibited

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447 evaporite formation. (ii) The second scenario (the evaporite mode) involves more arid conditions
448 leading and reduced riverine influx. This leads to the formation of near-costal evaporated water
449 masses sinking downslope (density cascading) where they accumulate in marginal basins. The
450 observation that Rosetta selenite crystals are large in size but low in number, points to a lower
451 salinity and the formation of a limited number of selenite nuclei (e.g. Lugli *et al.*, 2010). A typical
452 salinity range in modern selenite depositional environments is 110-300 g/l (e.g. Ortí, 2011;
453 Natalicchio *et al.*, 2014), corresponding to typical Sr contents of 1000-2600ppm (Ortí *et al.*, 1984).

454 The cyclical alternation of carbonate–chert couplets may (or may not) be ascribed to
455 astronomical-driven climatic fluctuations. By analogy with Messinian mudstone–gypsum precessional
456 cycles of the Mediterranean Basin (e.g. Dela Pierre *et al.*, 2011; Manzi *et al.*, 2013), a 20-kyr duration
457 of each evaporite-radiolarite cycle seems at least possible. In the absence of a reliable age model for
458 these rocks, this debate, however, must remain entirely speculative at present.

459
460 **Rosetta selenites interpreted in their environmental context and comparison with analogue**
461 **deposits**

462 *Factors controlling gypsum morphologies*

463 Laboratory experiments documented that gypsum morphologies are influenced by factors such as
464 the degree of evaporation, the presence or absence of other evaporite minerals, the brine
465 temperature, the amount of organic matter, and the seawater pH (e.g. Cody & Cody, 1988; Aquilano
466 *et al.*, 2016). Cody & Cody (1988) for example, argued the presence of significance amounts of
467 organic matter may lead to rosette-shaped growth forms. Given that few (perhaps none?) natural
468 evaporite depositional environments are devoid of organic matter, this notion seems difficult to
469 place in context in the studied deposits. Moreover, crystals that precipitate from warmer seawater
470 tend to be larger and more idiomorphic in nature (Cody & Cody, 1988). All of these considerations
471 are potentially valuable but given that the interpretation of field evidence in these metamorphic
472 rocks is less than trivial, it remains unclear to what degree these experiments can be applied to the
473 case example described here. In the view of the authors, it is thus perhaps more helpful to make use
474 of a contrast-comparison with the much better studied Messinian (Late Miocene) and Badenian
475 (middle Miocene of the central Paratethys; Hohenegger *et al.*, 2014; the top Burdigalian to the mid-
476 Serravalian, i.e., 18.3 to 16.3 Ma) evaporite deposits (Figs 16 to 18).

477
478 *Upward radiating selenite fans*

One of the chief characteristics of the meta-selenites discussed here is the significant length of individual crystals reaching up to 1.5 meters. In order to allow for these large crystals to form, a precipitation environment that provides stable physico-chemical conditions over long periods (likely months and years) and a sufficient fluid oversaturation is required. In general, large crystals are the result of slow growth rates and salinity conditions close to equilibrium (e.g. Rosell *et al.*, 1998). Upward-growing selenite gypsum fans form dome-like structures and are common both in modern and in ancient evaporitic environments (Bäbel, 2007; Lugli *et al.*, 2010; Ortí, 2011). Crystal growth is initiated from a nucleation point at the sediment-water interface and crystals continue to grow in a radial array as long as open space and an SO_4 -saturated brine is present. In the case of the meter-sized Rosetta meta-selenite fans, nucleation of crystalline gypsum took place on a seafloor formed by fine-grained siliceous sediments (Fig. 16A). Due to increasing weight of the selenite fans, the evaporites sunk into siliceous sediments at the seafloor creating load structures (Fig. 16A). This is considered clear evidence for a syndepositional, as opposed to diagenetic, origin of these features. Perhaps in analogy with the meta-selenites observed in the Anatolian Rosetta Marble, giant selenite crystals (Fig. 17C and D) and palisades made up of stacked swallow-tail twinned crystal (Fig. 17E and F) are a common texture of both Badenian (e.g. Bäbel, 1987) and Messinian (e.g. Lugli *et al.*, 2010; Ortí, 2011) evaporite deposits. The abundant radiating fans of crystals observed in the Anatolian meta-selenite fabrics have similar analogues in the Miocene deposits represented by domal- or radial fan-like structures (Figs 18A and C). Tilted upward oriented selenite fans observed in the Rosetta Marble share similarities with such from the Badenian evaporites explained as the results of unidirectional currents (e.g. Bäbel, 2005). Sabre-like crystals are typical features of the Rosetta Marble and form bundles up to 1.5 m in length. Sabre-like curved crystals are frequently found in Miocene evaporite deposits and occur in bundles or as individual crystals with variable dimensions embedded in a fine-grained matrix (Fig. 19A to D).

Bedding-parallel selenite fans

Bedding-parallel selenite fans show a range of morphotypes (Fig. 16). Formation models that provide an explanation of all three categories (central point, flower-like and concentric) include the following: (i) cutting effects at the outcrop scale and (ii) restricted growth (Fig. 16D). In the first case, upward oriented, domal crystal arrays are amalgamated. Individual crystals within each fan can be straight or curved depending on the environmental conditions during growth. Truncation of these fans by erosion (turbidites or less saline waters causing a dissolution of the uppermost layers) may lead to central point (i) (straight rods) and flower-like (ii) (curved rods) horizontal crystal fans oriented parallel to bedding planes. In the latter case, bedding parallel growth is considered a primary feature

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513 resulting from a shallow pycnocline and a limited number of crystallization nuclei (e.g. Lugli *et al.*,
514 2010). Small rods in the center of Rosetta textures were likely restricted by the shallow pycnocline
515 and ceased to grow when reaching the upper boundary of the brine layer. A similar mechanism was
516 proposed for the Messinian “branching selenite facies” (Lugli *et al.*, 2010), a peculiar type of
517 evaporite showing growth habits that are more laterally than vertically oriented. Concentric
518 horizontal Rosettas may have formed on the seafloor when the pycnocline was extremely shallow. In
519 addition, subsequent compaction by overlying sediments causing an extra flattening of these
520 features cannot be excluded.

521

522 *Downward-oriented selenite fans*

523 With reference to downward-oriented selenite fans, only few analogues exist in the geological record
524 (Ayllon-Quevedo *et al.*, 2007) and in the Recent (Fig. 18A and C). Clearly, this growth fabric is the
525 most challenging encountered in the Rosetta Marble facies, but perhaps also the most spectacular
526 one. Similar to upward-oriented selenite fans, crystal growth is initiated from a central nucleation
527 point at the seafloor and subsequently, selenite rods grow downwards and displace the host
528 sediment. This processes as such is not an uncommon feature and the displaced host sediment can
529 either be incorporated in the crystal lattice as solid inclusions or pushed away from the crystallization
530 front. In a study from the Laguna Madre (Texas), McBride *et al.* (1992) describe two fabrics of
531 gypsum growing in terrigenous sands in the phreatic zone. The former results from the slow (non-
532 displacive) precipitation of gypsum between quartz sand grains forming a cement phase. The other
533 fabric is the fast growth mode; here gypsum that is largely free from sand particles and displaces the
534 host sandy sediment and forms limpid crystal clusters up to 50 cm large. If the Laguna Madre gypsum
535 deposits represent to some degree analogue precipitates, then the downward-oriented radial arrays
536 typify periods of very rapid, displacive gypsum growth from highly-supersaturated pore fluids in very
537 soft siliceous sediment and a pycnocline that was essentially at the seafloor. Nevertheless, these
538 replacive or displacive fabrics are not well understood in terms of their formation and problems were
539 discussed for mainly calcitic syntaxial overgrowth cements. It seems at least possible that that the
540 original sediment was made up of gypsum-rich ooze subsequently replaced by the diagenetic
541 selenites. Modern case examples documenting perhaps similar processes include the ‘Daisy-head
542 gypsum’ from Texas and the ‘Daiys-bed gypsum’ from Cumbria, UK (Warren *et al.*, 1990). There,
543 phreatic fluids slowly infiltrate an anhydrite bed and radiating gypsum crystals grow pervasively,
544 often with a dolomite crystal as nucleation center. Brecciation is a typical phenomenon in evaporitic
545 rocks witnessing solution-induced collapse (e.g. Swennen *et al.*, 1990). In the pseudomorphosed

meta-selenite unit in Turkey, brecciation of fine laminated gypsum layers was recognized in at least one outcrop (Fig. 18 E and F).

548

Interpretation of meta-selenite geochemical data in the context of subduction and exhumation pathways

Bulk carbon isotope data

Bulk $\delta^{13}\text{C}_{\text{meta-selenite}}$ data (mean: +1.8‰) plot within the range of reconstructed middle Cretaceous seawater DIC values (Fig. 12; Veizer *et al.*, 1997). Obviously, this comparison must be taken with care as the Veizer *et al.* (1997) data are chiefly based on biogenic calcite as opposed to the rock samples discussed here.

The transformation of selenite to aragonite during burial diagenesis and following metamorphism in the context of subduction clearly affected the isotope signatures of the meta-selenites. Bacterial sulphate reduction and thermochemical sulphate reduction are the most common processes known to guide the transformation reaction from sulphate to carbonate (Machel, 2001). Both processes are expected to lead to ^{13}C -depleted carbon isotope values (Rouchy *et al.*, 1998). Bacterial sulphate reduction is a process that commonly obliterates the former gypsum crystal morphologies (Machel, 2001). In the case of Anatolia's Rosetta Marble, even subtle morphological features of the gypsum crystals (swallow-tails, skeletal-fibrous crystals, twin planes etc.), are preserved. Hence, bacterial sulphate reduction is ruled out here. Conversely, thermochemical sulphate reduction is known to result in gypsum pseudomorphs that preserve morphological features of their precursor minerals (Fenandés-Díaz *et al.*, 2009). Thermochemical sulphate reduction along a subduction geotherm takes place at temperatures of 100–180°C (Machel, 2001) but within the pressure field of aragonite (Fig. 2). This interpretation is in line with the observation that Sr concentrations of the selenite pseudomorphs (up to 3500 ppm) are elevated. Given that the calcite crystal lattice does not favor the incorporation of Sr, in contrast to that of aragonite (Katz *et al.*, 1972), the direct transformation of selenite to aragonite is favored here. The obvious problem in this chain of arguments lays with the interpretation of the what seem marine seawater DIC ratios of the Rosetta Marble which requires a discussion of the carbon sources during selenite-to-carbonate transformation.

In the context of transformation processes during subduction, several possible carbon sources must be considered. Seawater stratification combined with a restricted exchange of oxygen-depleted brines with marginal basins—as well as suboxic intraformational brines—favors the

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578 accumulation of organic-rich deposits (e.g. Roveri *et al.*, 2016). Whereas the Messinian deep-water
579 evaporites exhibit a high petroleum potential (Roveri *et al.*, 2016), the TOC of the Rosetta Marble is
580 low (<0.18%) but organic material rapidly decomposes at temperatures about ca. 160°C (Machel,
581 2001) and it is mainly kerogen and bitumen that remains. During the subduction (Fig. 2), the well-
582 defined pressure–temperature field is reached where most organic matter has transformed to gas
583 and bitumen has been transformed to graphite (Staplin, 1969). Methane as a possible reactant is
584 reactive, mobile, and is largely available (Machel, 2001). Methane is the final product of several
585 disintegration processes, indicating that larger molecules could be the primary source of CH₄. To
586 interpret the rather ¹³C-enriched values of the Rosetta Marbles, several carbon sources have to be
587 taken into account. Most CH₄ sources display strongly ¹³C-depleted values (Peckmann & Thiel 2004):
588 These include biogenic, bacterial and microbial methane (between -50‰ and -110‰; Whiticar *et al.*,
589 1986; Whiticar, 1999), thermogenic and non-bacterial methane (-30‰ to -50‰; Sackett, 1978),
590 geothermal, hydrothermal and crystalline methane (-20‰; Botz *et al.*, 2002 and references therein),
591 and petroleum (-25‰ to -35‰; Roberts and Aharon, 1994). These CH₄ isotope signatures may result
592 in carbonate rocks with distinctive and highly variable δ¹³C values such as the gas hydrates associated
593 carbonates (-60‰; Bohrmann *et al.*, 1998; Greinert *et al.*, 2001), and the mud volcanoes and
594 methane seep carbonates (-60‰ to +36‰; Clari *et al.*, 2004; 2009; Pekmann and Thiel, 2004;
595 Natalicchio *et al.*, 2012; Tassi *et al.*, 2012; Oppo *et al.*, 2013;). In addition, a mantle-derived carbon
596 source exhibits δ¹³C values in the range of -3‰ to -8‰ (Pineau & Javoy, 1983; Des Marais & Moore,
597 1984; Matthey *et al.*, 1984). Gas mixtures of different carbon sources due to vertical or lateral gas and
598 fluid migration and diffusion are common and complicates the interpretation of the isotope data
599 obtained here. In the following, the carbon isotope fractionation processes related to thermogenic
600 and bacterial methane production (methanogenesis) and to gas hydrates and cold seep carbonates
601 formation are considered in more detail.

602 The δ¹³C_{CH₄} of thermogenic gases becomes progressively enriched in ¹³C with increasing
603 maturity, eventually approaching the ¹³C/¹²C of the original organic matter or kerogen (and rarely
604 even heavier) (Whiticar, 1999). However, the resulting values remain negative. In situ produced CH₄
605 by methanogenesis (CH₃-A + H₂O → CH₄ + CO₂ + A-H) is a common reaction in modern wetlands
606 (Whiticar, 1999). The CO₂ and CH₄ byproducts generated through methanogenesis (bacterial
607 methane formation by carbonate reduction) show very distinct carbon isotopic compositions with
608 ¹³C-rich CO₂ and ¹³C-poor CH₄ products (Whiticar, 1999; Pierre *et al.*, 2002; Natalicchio *et al.*, 2012).
609 This might imply that CO₂ instead of CH₄ was involved in the sulphate reduction reaction of Anatolian
610 precursor gypsum. This is because, in-layer produced C could be isotopically similar to rock-buffered
611 δ¹³C values. Molecules with lower isotopic mass diffuse and react more rapidly and thus are utilized
612 more frequently than the isotopically heavier species (Whiticar, 1999). In a rock dominated system,

the preferential removal of the isotopically lighter molecules from the carbon pool during methanogenesis results in a progressive shift in the residual substrate towards heavier, ^{13}C -enriched values (Whiticar, 1999) and fractionation factors decreased with increasing temperature during subduction.

In marine sediments, a distinct diagenetic zonation for CH_4 is observed: a sulphate reduction (methane consumption) zone in the uppermost meters, followed by a CH_4 oxidation zone, and a CH_4 formation/production zone at the bottom (Claypool & Kaplan, 1974; Whiticar *et al.*, 1986). Usually anaerobic oxidation of methane (Boetius *et al.*, 2000) at the base of the sulphate zone is responsible for active, albeit incomplete, CH_4 removal. For complete sulphate reduction, the CH_4 influx from deeper levels must have been higher than the consumption rates. Analogous to methanogenesis, the bacterial uptake of CH_4 is associated with a kinetic isotope effect that enriches the residual CH_4 in the heavier isotope. A similar diagenetic zonation is a possible scenario that might explain the ^{13}C variances in upper and lower parts of the Rosetta Marble sections studied here.

Cold seep carbonates are generally typified by low $\delta^{13}\text{C}$ values since they inherit the strong ^{13}C -depletion relative to the methane gas (Peckmann & Thiel, 2004). However, $\delta^{13}\text{C}$ values $> +5\text{‰}$ have been also reported for individual carbonates from ancient seep deposits (Gaillard *et al.*, 1992; Peckmann *et al.*, 1999, 2002, 2003; Natalicchio *et al.*, 2012); these values likely result from the formation of ^{13}C -enriched carbonate minerals in the zone of methanogenesis (Peckmann & Thiel, 2004). With regard to the ^{13}C -enriched values of the Rosetta marble meta-selenites, a carbon source from methanogenesis should not be excluded *a priori*.

With reference to gas hydrates, Pierre *et al.* (2002) report on chemostratigraphic patterns from Late Miocene deposits that might be comparable with those found in the case of the Feslügen and Karaböğürtlen sections. The carbon isotopes show a distinct shift to ^{13}C -enriched values in the lower part (up to 9.25‰), whereas the $\delta^{18}\text{O}$ values display the opposite trend. Generally, these concepts might explain the patterns and absolute values of meta-carbonates measured in the context of this section. Care must be taken, however, as these rocks have suffered significantly more pervasive overprint during burial and metamorphism compared to the case examples documented in Pierre *et al.* (2002). Carbonates that precipitate during gas hydrate formation are ^{13}C -enriched, whereas decomposition of gas hydrates lead to low $\delta^{13}\text{C}$ values in carbonates. Gas hydrates are therefore a possible source for the heavy carbon in the selenite-to-aragonite reaction of the Rosetta Marble. It must be emphasized that tangible evidence for the presence of former gas hydrates in these sections is lacking. This does not rule out, however, that deeper seated gas hydrates released ^{13}C -enriched carbon into the system subsequently to be built into the meta-selenites under study.

Concluding, these carbon isotope data seem to support a seawater- and rock-dominated

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647 geochemical system resulting in meta-selenites that preserved a seawater- and rock-dominated
648 geochemical system resulting in meta-selenites that preserved their depositional isotope signature.
649 The problem lies with the transition from gypsum to aragonite during subduction that is usually
650 related to strongly ¹³C-depleted CH₄. Hence, even when mineralogy-driven (aragonite) fractionation
651 is taken into account (Waite & Swart, 2015), one or several sources of ¹³C-enriched carbon should be
652 considered. Given the limited outcrop conditions and the generally dispersed and incomplete rock
653 record of these metamorphic units, all of these considerations must at present remain on the level of
654 working hypotheses. Potentially, component-specific carbon isotope analysis has the potential to
655 shed light on these complex processes. This, however, must be the topic of further research.

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657 *Bulk oxygen isotope data*

658 Mean bulk $\delta^{18}\text{O}_{\text{meta-selenite}}$ isotope ratios (-1.6‰) fall within the boundaries of well-preserved marine
659 carbonate materials of middle Cretaceous age. Generally, evaporation of seawater leads to ¹⁸O
660 enriched values (up to +6‰), but depleted $\delta^{18}\text{O}$ values in evaporite mineral fluid inclusions have
661 been reported too (mixing with meteoric fluids; Knauth & Beeunas, 1986). Concentration of a
662 hypersaline brine show a shift in the $\delta^{18}\text{O}$ values of about +4.0‰ (Longinelli, 1979). Crystallization of
663 gypsum further shifts the $\delta^{18}\text{O}$ to +5.5‰ (Longinelli, 1979). Dehydration of gypsum at temperatures
664 of >50°C during transformation to anhydrite could be potentially significant during the subduction of
665 the evaporite-chert successions, but no evidences of anhydrite morphologies could be found.
666 Isotopically, water in the crystal lattice of gypsum is enriched in ¹⁸O by about 4‰ relative to the
667 water from which it precipitates (Knauth & Beeunas, 1986). The exceptional preservation of the
668 morphological attributes of the meta-selenite crystals is considered convincing evidence for that
669 direct transformation of gypsum to aragonite without an anhydrite stage. In the case of the
670 successions discussed here, the fluid is predominantly seawater engulfed in the subduction zone and
671 pore-fluid contained within the rock units. The question is, however, to which degree the aquifer
672 fluid and its geochemical properties are isolated from the small volumes of diagenetic fluid at the site
673 of micro-scale dissolution-precipitation processes (Pingitore, 1982) that govern the gypsum to
674 anhydrite neomorphism?

675 Regarding temperature, the sulphate-to-carbonate-reaction is exothermic, i.e., bacterial
676 sulphate reduction yields energy of $F^{25^\circ\text{C}} = -40.6$ kcal per mole of reacting sulphate (Decker *et al.*,
677 1970). The produced energy increased the bulk rock and fluid temperature and might thus induce a
678 fractionation towards ¹⁸O-depleted values (Pierre & Rouchy, 1988). Elevated temperatures might
679 induce the energy required to neomorphose gypsum to aragonite rather than calcite during sulphate

reduction reaction even outside of the thermodynamic stable field of aragonite. Volume-for-volume mineral replacement of sulphate ($74.31 \text{ cm}^3/\text{mole}$) by aragonite ($34.16 \text{ cm}^3/\text{mole}$) must have taken place under partly open system conditions as otherwise the generation of secondary porosity, *in situ* brecciation and collapse phenomena must be expected (Berner, 1971; Pierre & Rouchy, 1988). This is, with very rare exception not the case in the section studied here.

Circumstantial evidence for the oxygen isotope signature of the rocks discussed here comes from Carrara marbles that has seen deep burial and metamorphic overprint and temperatures of 200-350°C. Carrara marbles bulk oxygen isotope value plot in the field of 'normal' marine values (Ferry *et al.*, 2002; Ritter *et al.*, 2015). The most likely interpretation is that of low porosity rock units with fluid-to-solid ratios being essentially that of a rock buffered system (Ritter *et al.*, 2015; Pingitore, 1982; Berger *et al.*, 2016). Temperature-dependent oxygen isotope fractionation decays as $1/T$ -squared rather than $1/T$ at increasingly higher temperatures and approaches nil at around 300°C. Hence, expecting very depleted oxygen isotope values is not in concert with the fundamentals of thermodynamics. Moreover, at these P - T conditions, diagenetic fluids are an admixture of CO_2 and H_2O and aqueous diffusion is a dominant factor. All of these factors represent a warning that conventional models applied to evaporite and carbonate diagenesis cannot be used here.

$^{87}\text{Sr}/^{86}\text{Sr}$ isotope ratios and Sr elemental concentrations

Calcite pseudomorphs after gypsum preserve the initial Sr elemental concentration as well as the initial $^{87}\text{Sr}/^{86}\text{Sr}$ isotope ratios (e.g. Palaeozoic anhydrite pseudomorphs from Belgium up to 2500 ppm; Dejonghe *et al.*, 1998). More radiogenic $^{87}\text{Sr}/^{86}\text{Sr}$ ratios may be caused by two reasons: (i) significant *in situ* ^{87}Rb decay following pseudomorphism; or (ii) addition of radiogenic Sr (continental runoff) (Dejonghe *et al.*, 1998). The Sr elemental abundances are consistent with Cretaceous sea water values. Similarly to what was above argued for other geochemical properties, this is best explained by a rock-dominated system. Averaged $^{87}\text{Sr}/^{86}\text{Sr}$ (bulk) ratios obtained from samples in the Fesleğen section agree with Late Cretaceous sea water values (McArthur *et al.*, 2001). The potentially stratigraphically older Akçakaya section yields averaged $^{87}\text{Sr}/^{86}\text{Sr}$ values, that are in better agreement with Mid-Late Cretaceous seawater ratios. The averaged $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of Karaböğürtlen is intermediate in nature and invariant throughout the section.

Summing up, it is tempting to observe that reconstructed regional stratigraphic ages agree with relative ages based on $^{87}\text{Sr}/^{86}\text{Sr}$ ratios and the McArthur *et al.* (2001) look-up table. Given that these are metamorphic rock that have seen subduction and uplift accompanied with mineralogical change from gypsum to aragonite and finally calcite, skepticism remains. Moreover, semi-restricted

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basins, that might have been the site of gypsum precipitation as studied here, may deviate in their seawater $^{87}\text{Sr}/^{86}\text{Sr}$ signature from the global ocean system (e.g. Roveri *et al.*, 2016). In the Messinian marginal basins, for instance, the progressive isolation from the Atlantic Ocean led to a progressive stepwise decrease in $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, while the global ocean values remained constant (e.g. Roveri *et al.*, 2016). Essentially, two end-member solutions for the Cretaceous Rosetta Marble deposits offer themselves: (i) either these rocks— despite very significant mineralogical alteration—preserved their near-pristine $^{87}\text{Sr}/^{86}\text{Sr}$ ratios to the present day in a closed system behavior; or (ii) a poorly understood diagenetic and metamorphic pathway resulted in diagenetic $^{87}\text{Sr}/^{86}\text{Sr}$ ratios that, due to the admixture of more or less radiogenic Sr sources, by coincidence, mimic Cretaceous seawater values. At present, the first interpretation seems more reasonable but implies processes that are not well investigated.

Arguments for a Mid-Late Cretaceous salinity crisis in the Middle Tethys and comparison with Aptian evaporites in the Proto-Atlantic

Data shown here are considered evidence for the existence of what are now lost (subducted) basins in the middle Tethys experiencing a salinity crisis perhaps during the Albian. The wide occurrence (ca. 600 km in extension) of these meta-selenites all along the Ören-Afyon zone plead for an over regional, basin-wide event that affected significant portions of a middle Tethyan branch. The stratigraphic thickness of the Rosetta Marble unit extends 1500-2000 meters, an observation that points towards a long-lasting salinity crisis. The studied meta-selenites were deposited in a hemipelagic sequence, established by abundant tests of radiolarians in the most distal part and turbiditic intervals in the relatively proximal part of the basin. According to paleo-geographic reconstructions (Dercourt *et al.*, 2000) the Tethyan basin was not entirely closed (rather bordered by continents and sills). Warm climatic conditions are reported for the Aptian-Albian times including a gradual warming into the Cenomanian (Frakes, 1999; Clarke & Jenkyns, 1999; Huber *et al.*, 1995; Pucéat *et al.*, 2003, 2007). In the upper Aptian, marginal salt deposits of 1 to 2 km stratigraphic thickness precipitated during the earliest opening stages of the Atlantic (Burkes, 1975; Chaboureaud *et al.*, 2012) and may, time wise, correlate with Anatolias selenite-pseudomorph units reported here. The Atlantic evaporite units are interpreted with intermittent spillovers into sub-sea-level grabens over a period of 1 to 5 Myr (Burke, 1975; Davison, 1999). Spillovers from different oceans over structural sills produced massive evaporite units including horizontal and vertical cycles at least for the evaporites south of the Equator. For the northern Aptian Atlantic evaporites, a hydrothermal origin is proposed by some authors (Hardie, 1990; Chaboureaud *et al.*, 2012). For the southern Atlantic salt, a desiccation model (Torsvik *et al.*, 2009; Chaboureaud *et al.*, 2012) as well as deep water brines are proposed (Burke,

1975). Among these, the Atlantic evaporites are perhaps best comparable to the Rosetta Marble meta-selenite case example and therefore, contribute to very significant seawater evaporation that has a bearing on global-ocean element mass balances of carbon and sulphur (Wortman & Chernyavsky, 2007).

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752 Conclusions

753 This paper reports on Cretaceous metamorphosed selenite pseudomorphs from western Anatolia (causally termed 'Rosetta Marble') that stand out by their exceptionally well preserved morphological features and 'marine' geochemical signatures. The extraordinary preservation of delicate textures, typical for selenite, suggests a thermochemical rather than biological sulphate reduction.

758 These rocks have seen high-pressure/low-temperature, i.e. subduction-related metamorphism and peak P – T conditions are estimated as 1.0–1.2 GPa and 300–400°C. Depending on the locality studied, meta-selenites alternate with meta-radiolarites. In terms of their lateral extension (600 km) and stratigraphic thickness (1.5–2 km), the rock-forming meta-selenite deposits of Anatolia provide evidence for a lost Mid to Late Cretaceous salinity crisis in the middle Tethys and must be considered in global ocean element mass balance calculations for this time interval. The Rosetta Marble of Anatolia is, to the knowledge of the authors, the best preserved and largest (in lateral dimension, thickness, and rock-forming character) rock body formed predominantly of selenite pseudomorphs known to science so far.

767 Carbon and oxygen isotopic values of bulk selenite pseudomorphs fall in the range of reconstructed Cretaceous sea water values. Carbon and oxygen isotope values show systematic variances in meta-selenites and host matrix, indicating a phase-dependend timing of mineral replacement. The Sr concentration of the calcitized meta-selenites is in agreement with pristine gypsum values and $^{86}\text{Sr}/^{87}\text{Sr}$ ratios that can be correlated to Cretaceous seawater values. These observations are contrasted by the meta-selenites complex diagenetic and metamorphic pathways (gypsum to aragonite to calcite) and perhaps best understood in the context of a fluid-lean, i.e. rock-dominated system controlled by aqueous diffusion and thin CO_2 – H_2O fluid films at crystal boundaries that are essentially isolated from the bulk subduction aquifer.

776 Along a reconstructed proximal-to-distal transect, the most distal (hemi-pelagic) association of meta-selenite-radiolarite couplets has, to the knowledge of the authors, no analogue in Recent or Cenozoic marine basins. An alternation of a radiolarian bloom stage, caused by upwelling of basinal

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waters and an evaporite deposition stage induced by density cascading brines that formed during arid conditions in the coastal area is proposed. The formation of massive gypsum deposit in a hemipelagic environment may provide support to the deep-water–deep-basin model suggested for the deposition of the Mediterranean evaporites during the Messinian Salinity Crisis.

From a conceptual point of view, it is suggested that metaselenites are perhaps underexplored archives in palaeoenvironmental research and merit considerably more attention.

Acknowledgements

We thank Marcel Horning for help with the thin section preparation and isotope sampling, Dr. Dieter Buhl and Dr. Andrea Niedermayr for light stable and radiogenic isotope analysis at the Ruhr-University Bochum and Philipp Balling for assistance in the field. This project is financed by DFG project OB80/50|IM444/14.

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FIGURE CAPTIONS

Fig. 1. Tectonic map of Turkey in an UTM36N coordinate system (based on Okay 2008, Pourteau *et al.*, 2010, Oberhänsli *et al.*, 2010, Çetinkaplan *et al.*, 2014, Scheffler *et al.*, 2016). Green stars represent Cretaceous Rosetta Marble localities, which are restricted to the Ören–Afyon Zone. The study area is outlined by a whitish box.

Fig. 2. Simplified pressure-temperature (*P–T*) diagram (after Scheffler *et al.*, 2016) showing the three-stage evolution of the Rosetta Marble formation during subduction and exhumation. Conditions for thermochemical sulphate reduction (TSR) are located in the aragonite and gypsum stability field. A combination of high-Si phengite-quartz-water thermobarometric modeling from white mica within the Rosetta Marble of Fesleğen (Dubacq *et al.*, 2010; Scheffler *et al.*, 2016), *P–T* calculations of adjacent units based on multi-equilibrium calculationns (Rimmelé *et al.*, 2005) and calculated *P–T* conditions of the western and eastern Afyon Zone (Pourteau *et al.*, 2014) determine the maximum *P–T* conditions (high pressure (HP) metamorphism). The retrograde path is initiated by the crossing of the aragonite–calcite transition line (Hacker *et al.*, 2005) at >200°C to account for the overall lack of preserved aragonite. Gypsum–bassanite–anhydrite reaction curves are from Yamamoto & Kennedy (1969). See supplementary Fig. B for background data.

Fig. 3. Three different facies types according to increasing distal position in the paleo-basin: (A) Type–locality Fesleğen. Selenite pseudomorph–containing marble, referred to as “Rosetta Marble”, is interbedded with meta-calc-arenitic (quartzite) units and aligned chert nodules. The upper layer boundary of the meta-arenitic beds is marked by an erosive surface. (B) Type–locality Akçakaya. Rosetta Marble thickly alternates with nodular and ribbon bedded chert and form a typical pelagic-appearing sequence in m-scale. (C) Type–locality Karaböğürtlen. Thin-bedded (a few cm’s) Rosetta Marble layers interbedded with radiolarian-rich chert and meta-wackestone. Scale: field book, 20 cm long; hammer length: 56.5 cm, finger width: 1.7 cm.

Fig. 4. Fesleğen stratigraphic section. The lower part of the section is characterized by layered arenitic intervals with erosive surfaces. Upsection, meta-chert proportion increases. The upper part of the section consists of a regular selenite-pseudomorph bearing marble–chert alternation. On most exposed bedding planes dm- to m-wide radial textures can be observed. Perpendicular to the bedding, fan textures are restricted to certain levels.

Fig. 5. Karaböğürtlen section and corresponding isotope data set. (A) Sampled section. The uppermost 11 meters represent the red pelagic part of the section. The lower part of the section is characterized by yellowish thickly bedded selenite-pseudomorph containing marble–chert alternations. (B) Detailed stratigraphic section of the uppermost 11 meters showing regular selenite pseudomorph–containing marble–chert couplets. (C) Close up of the uppermost 11 meters of the studied section. (D) Close up of the yellowish part of the outcrop. (E) Chemostratigraphy of isotope data. The uppermost 11 meters clearly differ in their $\delta^{13}\text{C}$, $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ isotope values from the lower part of the section. Maximal errors for oxygen-, carbon- and Sr-isotopes are smaller than the chosen symbol-size.

Fig. 6. Growth orientations of selenite pseudomorphs. Arrows point to stratigraphic upwards. (A) Dome-shaped fan growing on top of a previous fan. (B) Subparallel to leaning crystals. (C)

1139 Downwards growing crystal fan with nucleation point at the bottom of an overlaying chert layer. (D)
 1140 Up- and downward oriented fans with chert nodule as central nucleation point. (E) Radiating rods
 1141 radiating from an impurity-rich central surface. Growth is confined by upper and lower chert layers.
 1142 (F) Radiating rods initiating from a central point. Hammer length is 56.5 cm. Fesleğen surroundings,
 1143 Ören Unit.

1144 **Fig. 7.** Large scale horizontal/in-plane meta-selenite textures at bedding planes. (A) Radial
 1145 appearance of selenite-pseudomorph fans. (B) Complex interactions of textures due to space
 1146 competitions. Hammer length is 56.5 cm. Fesleğen surroundings, Ören Unit.

1147 **Fig. 8.** Crystal habits and morphotypes of selenite-pseudomorphs. (A) Rod-like crystal habits in grey
 1148 marble matrix. Rods consist of fibrous calcites. Note the pushed forward brown material on top of
 1149 the rods. (B) Swallowtail stacked crystals. (C) Fishbone-like radiating crystals in a quartzitic matrix. (D)
 1150 Christmas-tree shaped selenite pseudomorphs approaching dendritic habits. (E) Skeletal texture
 1151 (bunches of sabre-like crystals). (F) Crystal fronts. Hammer length is 56.5 cm, hammer shaft is 3 cm
 1152 wide; coin diameter is ~2.6 cm; pen length is 16 cm.

1153 **Fig. 9.** Selenite-pseudomorphs and meta-chert in micro-scale. (A) Elongated crystal habits outlined by
 1154 fine grained marl. Fesleğen, transmitted light. (B) Elongated crystal shapes. The marly material here
 1155 mainly consists of microcrystalline quartz and dolomite rhombs. Karaböğürtlen (lower section),
 1156 crossed polarizers. (C) Elongated crystals that grow from different directions. Free space is filled with
 1157 smaller crystals. Karaböğürtlen (upper section), transmitted light. (D) Elongated crystal habits in the
 1158 upper part of the picture and pseudo-hexagonal basal sections (c-axis towards viewer) in the central
 1159 part. Karaböğürtlen (upper section), transmitted light. (E) Transition between selenite-pseudomorphs
 1160 and meta-chert layers is characterized by an accumulation of partly zoned dolomite rhombs of
 1161 different sizes. Fesleğen, crossed polarizers. (F) Sharp transition between a selenite-pseudomorph
 1162 and a meta-chert layer. Chert layers comprise less dolomites towards the layer centers.
 1163 Karaböğürtlen, transmitted light.

1164 **Fig. 10.** (A) Calcite fibres (pseudomorph after aragonite) in a siliceous-carbonaceous matrix. Fesleğen,
 1165 crossed polarizers. (B) Calcified radiolarian relics in a meta-wackestone. Karaböğürtlen, transmitted
 1166 light. (C) Chert containing silicified radiolarian relics and zoned dolomite rhombs. Karaböğürtlen,
 1167 transmitted light. (D) Transition between a meta-wackestone and a chert layer. Both contain equally
 1168 sized radiolarian relics. Karaböğürtlen, transmitted light.

1169 **Fig. 11.** Cathodoluminescence images. (A, B) Despite recrystallization zonation of gypsum habits are
 1170 preserved. (C, D) Variable growth directions of the meta-selenites. (E) Primary and altered areas are
 1171 only distinguishable. (F) Selenite crystal habits replaced by a single calcite crystal (no aragonite fibers
 1172 are preserved here). Samples are from Karaböğürtlen.

1173 **Fig. 12.** $\delta^{13}\text{C}$ – $\delta^{18}\text{O}$ cross plot. Sample sites are shape coded, stratigraphic level within sections is color
 1174 coded. Almost all samples plot in the 69% confident field of mean mid-Cretaceous sea water. Most of
 1175 the samples plot within the mean Cretaceous sea water reconstruction of Veizer (1999). Fesleğen
 1176 and Karaböğürtlen sections show clusters according to the stratigraphic position of the samples. Dark
 1177 red and light red circles are sampled in the upper part of the Karaböğürtlen section, orange circles in
 1178 the lower part. Medium green triangles belong to samples coming from the upper part of the

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Fesleğen section, light green triangles to the lower part. Dark green triangles refer to samples taken close to the Fesleğen section, but not within.

Fig. 13. $\delta^{13}\text{C}$ data of all three sections (corresponding to different facies) in comparison. The sections are not temporally comparable to each other. The stratigraphic younger parts of the sections differ in their $\delta^{13}\text{C}$ values significantly. The stratigraphic older parts of the sections approximate each other. Color coding within sections refers to the stratigraphic position of sampling and is consistent with Fig. 12.

Fig. 14. Carbon isotope mapping of a Rosetta Marble rock slab. Note the clustering according to the sampled material.

Fig. 15. Depositional environmental model. (A) Gypsum growth mode. Regular spillovers of cascading brines serve as ion-supplies to the deeper and more distal parts. Gypsum growth takes place in restricted ponds and size of selenites correlate to the distance to the shore line. (B) Turbidite/Radiolarite deposition mode. Humid climate prevents wide evaporation. Upwelling water masses on shelf area serve for nutrient-rich water surface conditions that promote radiolarian bloom. Turbidites and radiolarites form at that stage. (C) Simplified stratigraphic sections corresponding from proximal to distal localities in the paleo basin.

Fig. 16. Observed growth geometries are documented and classified in the first column. Based on that, the primary growing conditions were reconstructed in the second column. (A) Upwards oriented fans grow at the sea floor (t_0 - t_1) and can be restricted by the pycnocline level (t_1). An alternation of fan-growing layers with Si-rich layers is causing the final appearance of the rock (t_3) (B) Downward oriented fans grow displacive into the soft substratum (t_0), which can be either Si-rich or Si-depleted. (C) A combination of A and B conditions is able to produce up- and downward oriented fans that are spherical in shape. (D) The most common horizontal radial crystals are either explained by cutting effects (1. Scenario), by restricted growth due to a shallow pycnocline level (2. Scenario), or, a combination of both scenarios.

Fig. 17. Textural comparison of Neogene selenitic gypsum deposits from the Mediterranean and the Paratethys basins, left column, with Cretaceous selenite pseudomorphs from Anatolia, right column. (A) Climate-driven alternations of gypsum and shale layers. Messinian, Sicily, Italy. (B) Regular selenite-pseudomorph-marble – meta-chert couplets. (C) Giant selenite intergrowth. Badenian, near Kraków, Poland. (D) Selenite pseudomorphs resembling giant intergrowth. (E) Stacked swallow-tail crystals (columnar symmetrical twins). Messinian, Piedmont, Italy. (F) Gypsum pseudomorphs resembling swallowtail twins. Hammer shaft width is 3 cm.

Fig. 18. Textural comparison of Neogene selenitic gypsum deposits, left column, with Cretaceous selenite pseudomorphs from Anatolia, right column. (A) Radiating gypsum crystals around tree trunks. Badenian, near Kraków, Poland. (B) Radiating selenite-pseudomorphs on a bedding plane. (C) Radiating selenite crystals perpendicular (up- and downward) to the bedding plane. Messinian, Sicily, Italy. (D) Radiating selenite pseudomorph crystals perpendicular (up- and downward) to the bedding plane. Picture is tilted, see original in Fig. 5. (E) Layerd gypsum with in-situ brecciation. Badenian, near Kraków, Poland. (F) Layerd marble (meta-gypsum) with in-situ brecciation.

Fig. 19. Textural comparison of Neogene selenitic gypsum deposits with Cretaceous selenite pseudomorphs from Anatolia. (A) Large sabre-like selenite crystal in a gypsum matrix. Bedenian, Kraków, Poland. (B) Large sabre-like selenite pseudomorph crystal in a marble matrix. (C) Curved sabre selenite crystals in a gypsum matrix. Bedenian, Kraków, Poland. (D) Curved sabre-like selenite pseudomorph crystal in a marble matrix. Note the calcite fibres that are pseudomorphic after aragonite. (E) Growing surfaces within a twinned selenite crystal. Arrow indicates growing direction. Messinian, Piedmont, Italy. (F) Growing surfaces of selenite pseudomorph crystals. (G) Re-entrant angle (dark gray portion) and twinning plane of a swallow-tail selenite crystal. Bedenian, Kraków, Poland. (H) Dark grey line (arrow) within swallowtail selenite pseudomorph crystals as relict of an impurity-rich twin plane.

1228

1229 TABLE HEADINGS

1230

1231 Table 1

1232 Oxygen and Carbon isotope data. An outlier from Akçakaya was excluded: $\delta^{13}\text{C} = -0.64\text{‰}$ and $\delta^{18}\text{O} =$
1233 -6.65‰ . An outlier from “All samples Feslegen” was excluded, probably a secondary vein was
1234 sampled: $\delta^{13}\text{C} = -0.75\text{‰}$ and $\delta^{18}\text{O} = -3.01\text{‰}$.

1235

1236 Table 2

1237 Strontium isotope data.

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Tectonic map of Turkey in an UTM36N coordinate system (based on Okay 2008, Pourteau et al., 2010, Oberhänsli et al., 2010, Çetinkaplan et al., 2014, Scheffler et al., 2016). Green stars represent Cretaceous Rosetta Marble localities, which are restricted to the Ören–Afyon Zone. The study area is outlined by a whitish box.

170x81mm (300 x 300 DPI)

Simplified pressure-temperature (P-T) diagram (after Scheffler et al., 2016) showing the three-stage evolution of the Rosetta Marble formation during subduction and exhumation. Conditions for thermochemical sulphate reduction (TSR) are located in the aragonite and gypsum stability field. A combination of high-Si phengite-quartz-water thermobarometric modeling from white mica within the Rosetta Marble of Fesleğen (Dubacq et al., 2010; Scheffler et al., 2016), P-T calculations of adjacent units based on multi-equilibrium calculations (Rimmelé et al., 2005) and calculated P-T conditions of the western and eastern Afyon Zone (Pourteau et al., 2014) determine the maximum P-T conditions (high pressure (HP) metamorphism). The retrograde path is initiated by the crossing of the aragonite-calcite transition line (Hacker et al., 2005) at >200°C to account for the overall lack of preserved aragonite. Gypsum-bassanite-anhydrite reaction curves are from Yamamoto & Kennedy (1969). See supplementary Fig. B for background data.

119x78mm (300 x 300 DPI)

Three different facies types according to increasing distal position in the paleo-basin: (A) Type-locality Fesleğen. Selenite pseudomorph-containing marble, referred to as "Rosetta Marble", is interbedded with meta-calc-arenitic (quartzite) units and aligned chert nodules. The upper layer boundary of the meta-arenitic beds is marked by an erosive surface. (B) Type-locality Akçakaya. Rosetta Marble thickly alternates with nodular and ribbon bedded chert and form a typical pelagic-appearing sequence in m-scale. (C) Type-locality Karaböğürtlen. Thin-bedded (a few cm's) Rosetta Marble layers interbedded with radiolarian-rich chert and meta-wackestone. Scale: field book, 20 cm long; hammer length: 56.5 cm, finger width: 1.7 cm.

170x37mm (300 x 300 DPI)

Fesleğen stratigraphic section. The lower part of the section is characterized by layered arenitic intervals with erosive surfaces. Upsection, meta-chert proportion increases. The upper part of the section consists of a regular selenite-pseudomorph bearing marble-chert alternation. On most exposed bedding planes dm- to m-wide radial textures can be observed. Perpendicular to the bedding, fan textures are restricted to certain levels.

170x153mm (300 x 300 DPI)

Karaböğürtlen section and corresponding isotope data set. (A) Sampled section. The uppermost 11 meters represent the red pelagic part of the section. The lower part of the section is characterized by yellowish thickly bedded selenite-pseudomorph containing marble–chert alternations. (B) Detailed stratigraphic section of the uppermost 11 meters showing regular selenite pseudomorph–containing marble–chert couplets. (C) Close up of the uppermost 11 meters of the studied section. (D) Close up of the yellowish part of the outcrop. (E) Chemostratigraphy of isotope data. The uppermost 11 meters clearly differ in their δ¹³C, δ¹⁸O and ⁸⁷Sr/⁸⁶Sr isotope values from the lower part of the section. Maximal errors for oxygen-, carbon- and Sr-isotopes are smaller than the chosen symbol-size.

170x119mm (300 x 300 DPI)

Growth orientations of selenite pseudomorphs. Arrows point to stratigraphic upwards. (A) Dome-shaped fan growing on top of a previous fan. (B) Subparallel to leaning crystals. (C) Downwards growing crystal fan with nucleation point at the bottom of an overlaying chert layer. (D) Up- and downward oriented fans with chert nodule as central nucleation point. (E) Radiating rods radiating from an impurity-rich central surface. Growth is confined by upper and lower chert layers. (F) Radiating rods initiating from a central point. Hammer length is 56.5 cm. Fesleğen surroundings, Ören Unit.

170x169mm (300 x 300 DPI)

Large scale horizontal/in-plane meta-selenite textures at bedding planes. (A) Radial appearance of selenite-pseudomorph fans. (B) Complex interactions of textures due to space competitions. Hammer length is 56.5 cm. Fesleğen surroundings, Ören Unit.

245x188mm (300 x 300 DPI)

Crystal habits and morphotypes of selenite-pseudomorphs. (A) Rod-like crystal habits in grey marble matrix. Rods consist of fibrous calcites. Note the pushed forward brown material on top of the rods. (B) Swallowtail stacked crystals. (C) Fishbone-like radiating crystals in a quartzitic matrix. (D) Christmas-tree shaped selenite pseudomorphs approaching dendritic habits. (E) Skeletal texture (bunches of sabre-like crystals). (F) Crystal fronts. Hammer length is 56.5 cm, hammer shaft is 3 cm wide; coin diameter is ~2.6 cm; pen length is 16 cm.

170x158mm (300 x 300 DPI)

Selenite-pseudomorphs and meta-chert in micro-scale. (A) Elongated crystal habits outlined by fine grained marl. Fesleğen, transmitted light. (B) Elongated crystal shapes. The marly material here mainly consists of microcrystalline quartz and dolomite rhombs. Karaböğürtlen (lower section), crossed polarizers. (C) Elongated crystals that grow from different directions. Free space is filled with smaller crystals. Karaböğürtlen (upper section), transmitted light. (D) Elongated crystal habits in the upper part of the picture and pseudo-hexagonal basal sections (c-axis towards viewer) in the central part. Karaböğürtlen (upper section), transmitted light. (E) Transition between selenite-pseudomorphs and meta-chert layers is characterized by an accumulation of partly zoned dolomite rhombs of different sizes. Fesleğen, crossed polarizers. (F) Sharp transition between a selenite-pseudomorph and a meta-chert layer. Chert layers comprise less dolomites towards the layer centers. Karaböğürtlen, transmitted light.

170x191mm (150 x 150 DPI)

(A) Calcite fibres (pseudomorph after aragonite) in a siliceous-carbonaceous matrix. Fesleğen, crossed polarizers. (B) Calcified radiolarian relics in a meta-wackestone. Karaböğürtlen, transmitted light. (C) Chert containing silicified radiolarian relics and zoned dolomite rhombs. Karaböğürtlen, transmitted light. (D) Transition between a meta-wackestone and a chert layer. Both contain equally sized radiolarian relics. Karaböğürtlen, transmitted light.

120x89mm (150 x 150 DPI)

Cathodoluminescence images. (A, B) Despite recrystallization zonation of gypsum habits are preserved. (C, D) Variable growth directions of the meta-selenites. (E) Primary and altered areas are only distinguishable. (F) Selenite crystal habits replaced by a single calcite crystal (no aragonite fibers are preserved here). Samples are from Karaböğürtlen.

119x119mm (300 x 300 DPI)

$\delta^{13}\text{C}$ - $\delta^{18}\text{O}$ cross plot. Sample sites are shape coded, stratigraphic level within sections is color coded. Almost all samples plot in the 69% confident field of mean mid-Cretaceous sea water. Most of the samples plot within the mean Cretaceous sea water reconstruction of Veizer (1999). Fesleğen and Karaböğürtlen sections show clusters according to the stratigraphic position of the samples. Dark red and light red circles are sampled in the upper part of the Karaböğürtlen section, orange circles in the lower part. Medium green triangles belong to samples coming from the upper part of the Fesleğen section, light green triangles to the lower part. Dark green triangles refer to samples taken close to the Fesleğen section, but not within.

119x89mm (300 x 300 DPI)

$\delta^{13}\text{C}$ data of all three sections (corresponding to different facies) in comparison. The sections are not temporally comparable to each other. The stratigraphic younger parts of the sections differ in their $\delta^{13}\text{C}$ values significantly. The stratigraphic older parts of the sections approximate each other. Color coding within sections refers to the stratigraphic position of sampling and is consistent with Fig. 12.

80x124mm (300 x 300 DPI)

Carbon isotope mapping of a Rosetta Marble rock slab. Note the clustering according to the sampled material.

146x126mm (300 x 300 DPI)

Depositional environmental model. (A) Gypsum growth mode. Regular spillovers of cascading brines serve as ion-supplies to the deeper and more distal parts. Gypsum growth takes place in restricted ponds and size of selenites correlate to the distance to the shore line. (B) Turbidite/Radiolarite deposition mode. Humid climate prevents wide evaporation. Upwelling water masses on shelf area serve for nutrient-rich water surface conditions that promote radiolarian bloom. Turbidites and radiolarites form at that stage. (C) Simplified stratigraphic sections corresponding from proximal to distal localities in the paleo basin.

170x171mm (300 x 300 DPI)

Observed growth geometries are documented and classified in the first column. Based on that, the primary growing conditions were reconstructed in the second column. (A) Upwards oriented fans grow at the sea floor (t_0 - t_1) and can be restricted by the pycnocline level (t_1). An alternation of fan-growing layers with Si-rich layers is causing the final appearance of the rock (t_2) (B) Downward oriented fans grow displacive into the soft substratum (t_0), which can be either Si-rich or Si-depleted. (C) A combination of A and B conditions is able to produce up- and downward oriented fans that are spherical in shape. (D) The most common horizontal radial crystals are either explained by cutting effects (1. Scenario), by restricted growth due to a shallow pycnocline level (2. Scenario), or, a combination of both scenarios.

170x179mm (300 x 300 DPI)

Textural comparison of Neogene selenitic gypsum deposits from the Mediterranean and the Paratethys basins, left column, with Cretaceous selenite pseudomorphs from Anatolia, right column. (A) Climate-driven alternations of gypsum and shale layers. Messinian, Sicily, Italy. (B) Regular selenite-pseudomorph-marble – meta-chert couplets. (C) Giant selenite intergrowth. Badenian, near Kraków, Poland. (D) Selenite pseudomorphs resembling giant intergrowth. (E) Stacked swallow-tail crystals (columnar symmetrical twins). Messinian, Piedmont, Italy. (F) Gypsum pseudomorphs resembling swallowtail twins. Hammer shaft width is 3 cm.

170x152mm (300 x 300 DPI)

Textural comparison of Neogene selenitic gypsum deposits, left column, with Cretaceous selenite pseudomorphs from Anatolia, right column. (A) Radiating gypsum crystals around tree trunks. Badenian, near Kraków, Poland. (B) Radiating selenite-pseudomorphs on a bedding plane. (C) Radiating selenite crystals perpendicular (up- and downward) to the bedding plane. Messinian, Sicily, Italy. (D) Radiating selenite pseudomorph crystals perpendicular (up- and downward) to the bedding plane. Picture is tilted, see original in Fig. 5. (E) Layered gypsum with in-situ brecciation. Badenian, near Kraków, Poland. (F) Layered marble (meta-gypsum) with in-situ brecciation.

170x152mm (300 x 300 DPI)

Textural comparison of Neogene selenitic gypsum deposits with Cretaceous selenite pseudomorphs from Anatolia. (A) Large sabre-like selenite crystal in a gypsum matrix. Bedenian, Kraków, Poland. (B) Large sabre-like selenite pseudomorph crystal in a marble matrix. Bedenian, Kraków, Poland. (C) Curved sabre selenite crystals in a gypsum matrix. Bedenian, Kraków, Poland. (D) Curved sabre-like selenite pseudomorph crystal in a marble matrix. Note the calcite fibres that are pseudomorphic after aragonite. (E) Growing surfaces within a twinned selenite crystal. Arrow indicates growing direction. Messinian, Piedmont, Italy. (F) Growing surfaces of selenite pseudomorph crystals. (G) Re-entrant angle (dark gray portion) and twinning plane of a swallow-tail selenite crystal. Bedenian, Kraków, Poland. (H) Dark grey line (arrow) within swallowtail selenite pseudomorph crystals as relict of an impurity-rich twin plane.

170x168mm (300 x 300 DPI)

Table 1. Oxygen and Carbon isotope data. An outlier from Akçakaya was excluded: $\delta^{13}\text{C} = -0.64\text{‰}$ and $\delta^{18}\text{O} = -6.65\text{‰}$. An outlier from "All samples Feslegen" was excluded, probably a secondary vein was sampled: $\delta^{13}\text{C} = -0.75\text{‰}$ and $\delta^{18}\text{O} = -3.01\text{‰}$.

Sample sites	Spezifikation	Numb er of sample s	$\delta^{18}\text{O}$				$\delta^{13}\text{C}$			
			min	max	mean	$\pm s$	min	max	mean	$\pm s$
Feslegen	All samples	50	-3.84‰	-0.56‰	-1.46‰	0.1	+1.35‰	+2.52‰	+1.97‰	0.05
	Upper profile	16	-2.48‰	-0.93‰	-1.44‰	0.1	+1.91‰	+2.52‰	+2.32‰	0.04
	Lower profile	14	-3.84‰	-1.28‰	-1.79‰	0.9	+1.51‰	+2.27‰	+1.72‰	0.05
Karaböğürtlen	Upper profile	23	-5.35‰	-1.78‰	-2.72‰	0.07	+2.78‰	+3.93‰	+3.29‰	0.05
	Lower profile	15	-2.24‰	-0.50‰	-1.28‰	0.08	+1.13‰	+2.42‰	+1.67‰	0.05
Akçakaya		52	-2.20‰	-0.63‰	-1.79‰	0.09	+0.93‰	+2.24‰	+1.32‰	0.06
Bodrum		7	-1.77‰	-0.81‰	-1.41‰	0.06	0.99‰	2.27‰	+1.69‰	0.04
Ören		2	-0.925‰	-1.177‰	-1.051‰	0.1	0.973‰	0.980‰	+0.976‰	0.03

Table 1. Strontium isotope data.

Sample site	Detailed sample site	Number of samples	$^{87}\text{Sr}/^{86}\text{Sr}$			
			min	max	mean	$\pm 2 \sigma_{\text{mean}}$
Fesleğen	Upper profile	8	0.707479	0.707593	0.707522	0.000008
	Lower profile	5	0.707511	0.707664	0.707551	0.000008
Karaböğürten	Upper profile	5	0.7073379	0.7076933	0.7075578	0.000008
	Lower profile	6	0.7072873	0.7074792	0.7074066	0.000008
Akçakaya	Profile	12	0.707276	0.707664	0.707368	0.000008

Supplementary Material

Supplementary Figure A – 170mm

Fig. A. Sample location overview (see main text for coordinates). The map is based on Rimmelé *et al.* (2005), the official geological map of Turkey (MTA 2002) and Scheffler *et al.* (2016). Green triangle: Fesleğen, Blue rhomb: Akçakaya, Red circle: Karaböğürtlen, Yellow square: Ören, Violet crosses: Bodrum.

Supplementary Figure B – 170mm

Fig. B. PT-diagram including all data points published by Rimmelé *et al.* (2005) from the samples DEM007A + BAL001C (both are located north of the Akçakaya fault and represent the closest samples to the Fesleğen and Akçakaya samples), Ören0017D + Ören002C + Ören001H (all three locations are south of the Akçakaya fault) and ULA001B1 + ULA001B2 + ULA001C1 (all three locations are the closest samples to Karaböğürtlen). The arrows for these samples are suggested by Rimmelé *et al.* (2005). Furthermore, data from Pourteau *et al.* (2014) were included and suggested PT-path-arrows delineated. Quartz-water-phengite-thermobarometry calculations from Scheffler *et al.* (2016) are shown in transparent-grey, whereas the darkest grey area represents the field of highest probability. The data for this calculation are directly taken from Fesleğen-samples. Since the DEM007A + BAL001C samples, the western Afyon zone PT-path and the quartz-water-phengite-data are the most nearest to the location of interest, the blue area that is representing the peak PT-conditions, is mostly oriented on these data.

Dubacq, B., Vidal, O. and De Andrade, V. (2010) Dehydration of dioctahedral aluminous phyllosilicates: thermodynamic modelling and implications for thermobarometric estimates. *Contrib. Mineral. Petrol.*, **159**, 159–174

Fig. C. $\delta^{18}\text{O}$, $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ data of the Fesleğen profile. The y-axis represents the distance in the profile and correlates with the shown log on the right side of the figure. Note that the isotope data of the first 15 meters correlate with the thin and regular selenite pseudomorph bearing marble – meta-chert layers of the profile. Downsection the marble beds become thicker, the meta-chert layers decrease and quartzitic layers occur more frequently. For a more detailed sedimentological description of the lower part of this log, see Scheffler *et al.* (2016). Maximal errors for oxygen-, carbon- and Sr-isotopes are smaller than the chosen symbol-size.

Supplementary Figure D – 170mm

Fig. D. $\delta^{18}\text{O}$, $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ data of the upper part of the Karaböğürtlen section. The y-axis represents the distance in the profile and correlates with the shown log on the right side of the figure. Grey layers are selenite pseudomorph bearing marble, black layers are meta-chert intervals with occasionally meta-wackestone rims. Maximal errors for oxygen-, carbon- and Sr-isotopes are smaller than the chosen symbol-size.

Supplementary Figure E – 230mm high

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Fig. E. $\delta^{18}\text{O}$, $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ data of the Akçakaya profile. The y-axis represents the distance in the profile and correlates with the shown photograph of the sampled section. (A). The isotopes of this very regular profile are very homogeneous. The oxygen- and carbon-curves slightly follow the same up- and downs. (C) Character of the marble-chert-alternations of this profile in a close-up view. Maximal errors for oxygen-, carbon- and Sr-isotopes are smaller than the chosen symbol-size.

Supplementary Figure F – 230mm high

Fig. F. Rosetta Marble rock slab. Radiating white calcite rods are pseudomorphs after selenite. Circles mark the exact sampling spots of micro-drilling for ¹³C and ¹⁸O analysis.

Supplementary Figure G – 170mm

Fig. G. Oxygen isotope mapping of a Rosetta Marble rock slab. Note the clustering according to the sampled material.

Supplementary Figure H – 170mm

Fig. H. Boxplot of the ^{13}C Isotopes of the analysed rock slab. Distinguishable populations.

Supplementary Figure I – 170mm

Fig. I. Boxplot of the ^{18}O Isotopes of the analysed rock slab. Distinguishable populations.

Supplementary Data Table A: Carbon and Oxygen isotopes

The Table shows all Carbon and Oxygen data that were included in graphs and calculations of the paper. Not shown are data that have not fulfilled the quality criteria (too high max. amplitude, not enough CaCO₃ content for the measurement) and were therefore excluded. From samples that were measured twice, a mean value was calculated.

		corrected values									
		sample weight	max. Amplitude	d ¹³ C _{PDB}		d ¹⁸ O _{PDB-carbonate}			Position in the profile	Corresponding	
sample name	Nr.	[mg]	[V]	[‰]	± s	[‰]	± s	date	[cm]	Sr ratios	
Karaböğürtlen Profile									14000		
Kar1531	GB 55210	0.60	9715	3,93	0,03	-2,20	0,07	03.03.2016	13829		
Kar1412-B	GB 54698	0.40	4111	3,52	0,03	-2,45	0,03	14.01.2016	13809		
Kar1512-A	GB 54697	0.41	4971	3,84	0,05	-2,26	0,06	14.01.2016	13807		
Kar1515	GB 54359	0.43	6975	3,93	0,03	-1,97	0,05	16.12.2015	13688	0,707337856	
Kar1536	GB 55212	0.61	9859	3,35	0,04	-1,81	0,05	03.03.2016	13627		
Kar1508-A	GB 54382	1.26	4245	3,13	0,05	-2,42	0,05	16.12.2015	13512		
Kar1508-B	GB 54693	1.80	3419	2,93	0,05	-4,16	0,07	14.01.2016	13510		
Kar1534	GB 55216	0.55	7877	3,23	0,03	-2,25	0,02	03.03.2016	13412		
Kar1537	GB 55211	0.52	8089	3,20	0,04	-1,78	0,05	03.03.2016	13360		
Kar1535	GB 55214	0.62	8747	3,13	0,02	-1,81	0,04	03.03.2016	13338		
Kar1505-B	GB 54696	0.41	6422	3,17	0,04	-2,28	0,06	14.01.2016	13327	0,707477868	
Kar1505-A	GB 54695	0.40	5512	3,07	0,04	-2,29	0,05	14.01.2016	13325		
Kar1518-C	GB 54373	0.47	6847	3,17	0,02	-2,40	0,02	16.12.2015	13167		
Kar1518-A	GB 54687	0.40	6409	3,14	0,04	-5,35	0,04	14.01.2016	13166	0,707631826	
Kar1518-B	GB 54371	0.44	6393	3,23	0,05	-2,34	0,05	16.12.2015	13166		
Kar1503-D	GB 54684	0.42	5517	3,34	0,03	-4,00	0,04	14.01.2016	13103		
Kar1503-A	GB 54363	0.41	6861	2,78	0,03	-4,65	0,03	16.12.2015	13102	0,707648277	
Kar1503-B	GB 54364	0.48	7565	2,96	0,03	-3,71	0,06	16.12.2015	13102		
Kar1501	GB 54688	0.41	5413	3,12	0,04	-2,29	0,06	14.01.2016	13037	0,707693279	
Kar1502-D	GB 54692	0.55	4676	3,19	0,03	-2,71	0,05	14.01.2016	12969		
Kar1502-C	GB 54690	0.40	5696	3,48	0,04	-2,51	0,04	14.01.2016	12969		
Kar1502-B	GB 54379	1.73	6948	3,49	0,03	-2,46	0,06	16.12.2015	12969		
Kar1502-A	GB 54689	0.41	5606	3,27	0,04	-2,47	0,05	14.01.2016	12968		
Kar1519	GB 54342	0.42	7431	2,41	0,03	-2,24	0,08	15.12.2015	10898		
Kar1520-A	GB 54201	0.41	8928	1,87	0,02	-0,65	0,07	23.11.2015	9860	0,707467854	
Kar1521	GB 54346	0.43	7781	1,87	0,04	-0,50	0,05	15.12.2015	8125	0,707453847	
Kar1522-A	GB 54343	0.48	7437	1,36	0,03	-1,46	0,06	15.12.2015	7493		
Kar1522-B	GB 54344	0.42	7279	1,42	0,03	-1,58	0,05	15.12.2015	7490		
Kar1523-B	GB 54339	0.38	6693	1,47	0,03	-0,96	0,06	15.12.2015	7246		
Kar1523-A	GB 54338	0.41	7425	1,94	0,03	-0,90	0,05	15.12.2015	7245	0,707479239	
Kar1525A	GB 54329	0.38	6337	2,42	0,05	-1,08	0,05	15.12.2015	6109		
Kar1526	GB 54326	0.39	6236	1,75	0,02	-1,15	0,07	15.12.2015	4171	0,707406819	
Kar1527-A	GB 54334	0.39	6185	1,69	0,03	-1,31	0,05	15.12.2015	4152		
Kar1527-B	GB 54335	0.38	4580	1,13	0,03	-1,79	0,07	15.12.2015	2847		

Kar1527-C	GB 54337	0.42	5780	1,18	0,04	-1,86	0,09	15.12.2015	2846	
Kar1528-A	GB 54323	0.40	6342	1,20	0,04	-1,27	0,05	15.12.2015	2845	
Kar1528-B	GB 54325	0.39	6344	1,61	0,03	-1,01	0,05	15.12.2015	1245	0,707344830
Kar1530	GB 54328	0.42	6875	1,70	0,03	-1,48	0,05	15.12.2015	1180	0,707287252
Excluded because of very negative O values:										
Kar1509-B	GB 54361	0.39	6774	2,91	0,03	-13,25	0,05	16.12.2015		
Akçakaya Profile										
Fes1580	GB 54220	0.37	7354	1,10	0,04	-1,85	0,08	24.11.2015	10600	
Fes1579	GB 54218	0.39	7896	1,00	0,03	-1,95	0,08	24.11.2015	10436	0,707345247
Fes1578-B	GB 54214	0.39	7605	0,94	0,05	-2,01	0,07	24.11.2015	10167	0,707328856
Fes1577	GB 54219	0.41	8313	1,14	0,04	-1,85	0,06	24.11.2015	10072	
Fes1576	GB 54217	0.39	7989	1,18	0,04	-1,87	0,07	24.11.2015	9795	0,707393825
Fes1575-A	GB 54216	0.40	8048	1,20	0,03	-1,78	0,09	24.11.2015	9605	0,707321823
Fes1574-A	GB 54262	0.40	7081	1,25	0,02	-1,49	0,06	30.11.2015	9328	
Fes1573A	GB 54222	0.43	8594	1,33	0,02	-1,47	0,07	24.11.2015	8964	0,707326233
Fes1572-A	GB 54224	0.39	7538	1,40	0,03	-1,77	0,08	24.11.2015	8644	
Fes1572-B	GB 54225	0.41	8521	1,42	0,05	-1,71	0,07	24.11.2015	8644	
Fes1571-A	GB 54265	0.40	7391	1,37	0,03	-1,47	0,04	30.11.2015	8557	
Fes1570	GB 54215	0.40	7571	1,34	0,04	-1,59	0,07	24.11.2015	8306	0,707387865
Fes1569-A	GB 54294	0.41	8053	1,24	0,03	-1,46	0,07	30.11.2015	7900	
Fes1567-A	GB 54395	0.38	7063	1,01	0,06	-1,90	0,05	16.12.2015	7225	
Fes1566-A	GB 54287	0.40	7534	1,22	0,02	-1,48	0,05	30.11.2015	7017	
Fes1565-A	GB 54295	0.41	8084	1,21	0,02	-1,61	0,05	30.11.2015	6757	
Fes1564-A	GB 54362	0.40	6477	1,15	0,05	-1,64	0,05	16.12.2015	6368	0,707399845
Fes1563-A	GB 54299	0.42	7726	1,22	0,03	-1,90	0,06	30.11.2015	6082	
Fes1562-A	GB 54291	0.40	7521	1,57	0,02	-1,70	0,05	30.11.2015	5805	
Fes1562-B	GB 54293	0.43	8237	0,99	0,02	-1,92	0,08	30.11.2015	5805	
Fes1561-B	GB 54298	0.42	6917	1,00	0,03	-1,87	0,06	30.11.2015	5589	
Fes1560	GB 54290	0.40	7918	1,89	0,05	-1,76	0,07	30.11.2015	5277	0,707363844
Fes1559	GB 54289	0.39	7571	1,55	0,03	-1,86	0,03	30.11.2015	5009	
Fes1558-A	GB 54202	0.39	8134	1,70	0,03	-2,12	0,08	23.11.2015	4645	
Fes1557	GB 54347	0.42	7163	1,30	0,03	-2,18	0,06	15.12.2015	4455	
Fes1556-A	GB 54332	0.40	6843	1,83	0,01	-2,10	0,03	15.12.2015	4299	0,707314849
Fes1556-B	GB 54333	0.40	6318	1,33	0,04	-2,10	0,03	15.12.2015	4299	
Fes1555	GB 54341	0.40	6605	1,08	0,04	-2,07	0,09	15.12.2015	3936	
Fes1554-A	GB 54388	0.39	6288	1,13	0,04	-1,75	0,03	16.12.2015	3659	
Fes1553-A	GB 54284	0.41	5910	1,33	0,04	-1,85	0,05	30.11.2015	3321	
Fes1553-B	GB 54285	0.42	7918	1,12	0,02	-1,89	0,05	30.11.2015	3321	
Fes1552	GB 54286	0.43	8036	0,97	0,03	-2,08	0,03	30.11.2015	3148	0,707663834
Fes1551	GB 54331	0.40	6745	1,16	0,03	-2,00	0,05	15.12.2015	2897	
Fes1550-A	GB 54330	0.40	6873	1,54	0,05	-2,12	0,05	15.12.2015	2464	
Fes1549	GB 54241	0.42	8756	1,65	0,03	-1,99	0,09	24.11.2015	2352	
Fes1548-B	GB 54376	0.40	6549	1,52	0,05	-1,63	0,08	16.12.2015	2049	
Fes1547	GB 54248	0.39	6211	1,24	0,03	-2,20	0,09	24.11.2015	1910	
Fes1546	GB 54282	0.41	7830	1,63	0,02	-1,67	0,04	30.11.2015	1677	
Fes1545-A	GB 54270	0.41	7319	1,37	0,03	-1,72	0,03	30.11.2015	1408	0,707275867
Fes1545-B	GB 54271	0.40	7492	1,20	0,04	-1,83	0,04	30.11.2015	1408	
Fes1545-C	GB 54272	0.40	7591	1,10	0,02	-2,02	0,04	30.11.2015	1408	
Fes1544	GB 54252	0.44	8746	0,93	0,03	-2,09	0,09	24.11.2015	1149	

1											
2											
3											
4	Fes1543	GB 54251	0.40	8107	1,19	0,03	-2,03	0,08	24.11.2015	880	
5	Fes1541-A	GB 54247	0.42	8277	1,20	0,02	-1,97	0,08	24.11.2015	569	0,707293272
6	Fes1540-A	GB 54246	0.45	9136	1,06	0,03	-2,03	0,09	24.11.2015	422	
7	Fes1540-B	GB 54394	0.45	7465	1,14	0,03	-1,85	0,02	16.12.2015	422	
8	excluded outlier:										
9	Fes1548-A	GB 54374	0.40	6796	-0,64	0,02	-6,65	0,03	16.12.2015		
10	Fesleßen profile									4400	
11											
12	Fes1527	GB 54268	0.41	8049	2,31	0,03	-0,93	0,04	30.11.2015	4361	0,707524836
13	Fes1526	GB 54264	0.39	6291	2,33	0,02	-1,15	0,04	30.11.2015	4238	
14	Fes1525	GB 54238	0.42	8471	2,15	0,04	-0,94	0,07	24.11.2015	4186	0,707493842
15	Fes1523	GB 54239	0.42	8328	2,34	0,02	-1,37	0,07	24.11.2015	4062	0,707521856
16	Fes1522-A	GB 54278	0.39	7648	2,40	0,03	-1,06	0,08	30.11.2015	3986	0,707487226
17	Fes1522-B	GB 54281	0.38	7712	2,28	0,03	-1,34	0,04	30.11.2015	3986	
18	Fes1521	GB 54277	0.41	7579	1,91	0,02	-2,02	0,03	30.11.2015	3890	
19	Fes1520	GB 54229	0.41	8206	2,42	0,04	-1,10	0,08	24.11.2015	3824	0,707478821
20	Fes1519	GB 54230	0.41	8145	2,40	0,02	-0,97	0,10	24.11.2015	3680	0,707501233
21											
22	Fes1518-A	GB 54242	0.41	8223	2,25	0,04	-1,22	0,07	24.11.2015	3614	
23	Fes1518-B	GB 54243	0.40	8326	2,31	0,02	-1,33	0,08	24.11.2015	3614	
24	Fes1517	GB 54234	0.41	8359	2,36	0,02	-1,10	0,08	24.11.2015	3512	0,707592845
25	Fes1516	GB 54233	0.41	8482	2,49	0,03	-2,48	0,09	24.11.2015	3385	
26	Fes1515	GB 54236	0.41	8731	2,30	0,03	-2,21	0,06	24.11.2015	3312	
27											
28	Fes1514	GB 54275	0.44	8395	2,52	0,03	-1,61	0,06	30.11.2015	3230	
29	Fes1513	GB 54261	0.41	7282	2,31	0,04	-2,23	0,03	30.11.2015	3041	0,707576871
30	Fes1512	GB 54227	0.41	8629	1,92	0,02	-1,45	0,08	24.11.2015	2843	
31	Fes1511	GB 54276	0.42	7908	1,63	0,05	-1,42	0,06	30.11.2015	2401	0,707543254
32	Fes1510	GB 54274	0.39	7252	1,51	0,04	-1,55	0,05	30.11.2015	2190	
33											
34	Fes1509A	GB 54232	0.43	8652	1,91	0,03	-1,35	0,09	24.11.2015	1936	
35	Fes1509B	GB 54237	0.41	8016	1,57	0,03	-1,29	0,07	24.11.2015	1936	
36	Fes1508	GB 54226	0.42	8965	1,58	0,04	-1,45	0,07	24.11.2015	1493	0,707512856
37	Fes1507	GB 54283	0.41	7753	2,27	0,03	-1,57	0,05	30.11.2015	1275	
38	Fes1506	GB 54228	0.39	8737	1,74	0,04	-1,28	0,08	24.11.2015	882	0,707525849
39											
40	TÜ11 A				1,59	0,02	-1,59	0,04		709	
41											
42	Fes1505-A	GB 54273	0.41	7605	1,68	0,05	-2,25	0,05	30.11.2015	558	
43	Fes1505-B	GB 54389	0.43	7811	1,53	0,03	-3,84	0,05	16.12.2015	558	
44	Fes1503-A	GB 54385	0.41	6906	1,81	0,02	-2,30	0,04	16.12.2015	512	0,707663834
45	Fes1503-B	GB 54386	0.42	5829	1,63	0,03	-2,32	0,05	16.12.2015	511	
46	Fes1501-A	GB 54266	0.41	7075	1,65	0,05	-1,39	0,05	30.11.2015	197	0,707511246
47											
48	Additional Fesleßen samples for the C-O plot (close but not part of the profile):										
49	TU14A	GB 45233	0.40	4728	2,41	0,02	-0,85	0,06	18.07.2013		
50	TU14B	GB 45234	0.39	4659	2,34	0,02	-0,80	0,04	18.07.2013		
51	TU14C	GB 45235	0.41	5075	2,40	0,04	-0,78	0,03	18.07.2013		
52	TU14D	GB 45236	0.40	5248	2,34	0,03	-0,68	0,04	18.07.2013		
53											
54	TÜ15-A	GB 47214	0.42	6033	1,41	0,03	-0,65	0,07	15.04.2014		
55	TÜ15-B	GB 47216	0.41	5006	1,41	0,03	-0,76	0,06	15.04.2014		
56	TÜ15-C	GB 47217	0.50	6422	1,46	0,02	-0,56	0,05	15.04.2014		
57	TÜ15-D	GB 47218	0.55	6993	1,59	0,01	-0,79	0,05	15.04.2014		
58	TÜ11-B	GB 47229	0.40	6073	1,66	0,03	-2,11	0,03	15.04.2014		
59	TÜ11	GB 45231	0.40	4588	1,74	0,04	-1,79	0,06	18.07.2013		
60	TÜ11-A	GB 47226	0.41	5915	1,58	0,02	-1,63	0,02	15.04.2014		

TÜ11-A	GB 47227	0.42	6109	1,61	0,02	-1,56	0,04	15.04.2014
TÜ16-A	GB 47231	0.61	8888	1,50	0,02	-0,95	0,05	15.04.2014
Fes1303-A	GB 47238	0.38	5122	1,36	0,03	-2,08	0,08	15.04.2014
Fes1303-A	GB 47239	0.40	5329	1,35	0,01	-2,05	0,03	15.04.2014
Fes1303-B	GB 47240	0.50	7788	1,62	0,02	-0,89	0,02	15.04.2014
Fes1304-B	GB 47260	0.48	6497	2,19	0,02	-1,76	0,03	16.04.2014
Fes1304-B	GB 47261	0.48	6569	2,23	0,03	-1,57	0,04	16.04.2014
Fes1304-D	GB 47251	0.45	6214	2,34	0,04	-1,22	0,08	15.04.2014
TU2	GB 45245	0.51	6169	2,13	0,04	-2,10	0,06	18.07.2013
TU1.2	GB 45230	0.38	4841	2,43	0,04	-0,93	0,04	18.07.2013
Bodrum								
Bod1506	GB 54312	0.49	7559	2,00	0,04	-1,77	0,02	15.12.2015
Bod1507	GB 54313	0.49	7877	1,59	0,04	-1,34	0,04	15.12.2015
Bod1505	GB 54683	0.51	7079	1,41	0,03	-0,81	0,04	14.01.2016
Bod1501-A	GB 54318	0.47	4810	2,27	0,04	-1,42	0,03	15.12.2015
Bod1501-B	GB 54319	0.47	6039	2,27	0,03	-1,65	0,05	15.12.2015
Bod1504	GB 54321	0.44	7358	0,99	0,02	-1,16	0,04	15.12.2015
Bod1502	GB 54322	0.48	5745	1,28	0,03	-1,76	0,06	15.12.2015
Ören								
Ören1502-A	GB 54244	0.40	7357	0,98	0,03	-1,18	0,08	24.11.2015
Ören1502-B	GB 54245	0.42	8590	0,97	0,03	-0,93	0,10	24.11.2015
Rock slab mapping								
FesBig A	GB 60483	0.1215	5208	2,20	0,04	-0,59	0,07	11.01.2017
FesBig B	GB 60479	0.124	5445	2,19	0,04	-0,48	0,03	11.01.2017
FesBig C	GB 60474	0.1085	4294	2,15	0,07	-0,44	0,03	11.01.2017
FesBig D	GB 60470	0.1175	5138	2,18	0,07	-0,75	0,03	11.01.2017
FesBig E	GB 60466	0.115	4833	2,23	0,05	-0,77	0,03	11.01.2017
FesBig F	GB 60460	0.116	5085	2,29	0,07	-0,58	0,06	11.01.2017
FesBig G	GB 60484	0.1045	4153	2,23	0,07	-0,74	0,04	11.01.2017
FesBig H	GB 60480	0.116	4662	1,73	0,05	-0,75	0,06	11.01.2017
FesBig I	GB 60476	0.1185	4742	2,18	0,06	-0,53	0,04	11.01.2017
FesBig J	GB 60471	0.132	5493	1,78	0,02	-1,16	0,05	11.01.2017
FesBig K	GB 60467	0.128	4635	1,80	0,05	-1,07	0,05	11.01.2017
FesBig L	GB 60461	0.119	4581	1,82	0,05	-1,22	0,06	11.01.2017
FesBig M	GB 60485	0.123	4724	1,69	0,06	-1,27	0,08	11.01.2017
FesBig N	GB 60481	0.121	4462	1,76	0,04	-1,13	0,03	11.01.2017
FesBig O	GB 60477	0.1445	5407	1,68	0,04	-1,15	0,07	11.01.2017
FesBig P	GB 60472	0.1185	5110	1,92	0,06	-0,77	0,02	11.01.2017
FesBig Q	GB 60468	0.1095	4652	2,21	0,09	-0,87	0,04	11.01.2017
FesBig R	GB 60464	0.1135	4969	2,27	0,08	-0,67	0,05	11.01.2017
FesBig S	GB 60493	0.1125	5403	2,15	0,06	-0,93	0,05	17.01.2017
FesBig T	GB 60482	0.1175	4814	2,10	0,04	-0,71	0,04	11.01.2017
FesBig U	GB 60478	0.1185	3120	1,76	0,06	-0,15	0,14	11.01.2017
FesBig V	GB 60473	0.113	909					signal too small
FesBig V	GB 60579	0.516	5366	1,33	0,06	-2,12	0,03	23.01.2017
FesBig W	GB 60469	0.1165	4999	2,23	0,06	-0,63	0,03	11.01.2017
FesBig X	GB 60465	0.1135	3749	1,93	0,04	-0,47	0,02	11.01.2017
FesBig Y	GB 60494	0.1245	5695	1,91	0,06	-0,82	0,06	17.01.2017
FesBig Z	GB 60495	0.1180	5460	2,24	0,04	-0,74	0,05	17.01.2017

FesBig 3	GB 60498	0.1215	4519	1,96	0,05	-1,12	0,03	17.01.2017
FesBig 4	GB 60499	0.1155	4408	1,86	0,10	-1,33	0,04	17.01.2017
FesBig 5	GB 60500	0.1155	3723	1,85	0,04	-0,28	0,06	17.01.2017
FesBig 6	GB 60501	0.1105	5356	2,20	0,07	-0,79	0,03	17.01.2017
FesBig 7	GB 60502	0.1115	4956	2,27	0,05	-0,52	0,06	17.01.2017
FesBig 8	GB 60504	0.1270	6031	2,18	0,03	-0,76	0,04	17.01.2017
FesBig 9	GB 60505	0.1105	5262	2,29	0,07	-0,40	0,05	17.01.2017
FesBig 10	GB 60506	0.1125	1250					signal too small
FesBig 10	GB 60580	0.4135	5229	1,66	0,06	-1,88	0,04	23.01.2017
FesBig 11	GB 60507	0.1420	6842	2,07	0,05	-0,61	0,04	17.01.2017
FesBig 12	GB 60508	0.1390	995					signal too small
FesBig 12	GB 60583	0.5030	4813	0,90	0,02	-2,08	0,02	23.01.2017
Excluded because they are located too far from the main mapping area:								
FesBig 1	GB 60496	0.1105	4963	1,87	0,08	-1,10	0,03	17.01.2017
FesBig 2	GB 60497	0.1365	6815	1,94	0,06	-0,79	0,04	17.01.2017

Supplementary Data Table B: Sr isotopes

Dec 15

Standards	Value McArthur	Mean Value Bochum	± 2 s standard error	± 2 s standard diviation	number of repetitions [n]
NIST NBS 987	0,710247	0,710241	0,000002	0,000032	345
USGS EN-1	0,709175	0,709161	0,000002	0,000030	301

sample name or number	$^{87}\text{Sr}/^{86}\text{Sr}$ measured	± 2 s mean	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: NBS 987 value McArthur and NBS 987 measured with sample	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: USGS EN-1 value McArthur and USGS EN-1 measured with sample	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: NBS 987 value McArthur and NBS 987 Bochum mean value	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: USGS EN-1 value McArthur and USGS EN-1 Bochum mean value
NIST NBS 987	0,710241	0,000005	0,710247	0,710211	0,710247	0,710255
Fes1578-B	0,707323	0,000005	0,707329	0,707293	0,707329	0,707337
Fes1570	0,707382	0,000006	0,707388	0,707352	0,707388	0,707396
Fes1575-A	0,707316	0,000005	0,707322	0,707286	0,707322	0,707330
Fes-1576	0,707388	0,000005	0,707394	0,707358	0,707394	0,707402
Fes1508	0,707507	0,000005	0,707513	0,707477	0,707513	0,707521
Fes1506	0,707520	0,000005	0,707526	0,707490	0,707526	0,707534
Fes1520	0,707473	0,000005	0,707479	0,707443	0,707479	0,707487
USGS EN-1	0,709205	0,000006	0,709211	0,709175	0,709211	0,709219
NIST NBS 987	0,710223	0,000005	0,710247	0,710239	0,710229	0,710237
Fes1517	0,707587	0,000006	0,707611	0,707603	0,707593	0,707601
Fes1525	0,707488	0,000005	0,707512	0,707504	0,707494	0,707502

Fes1523	0,707516	0,000005	0,707540	0,707532	0,707522	0,707530
Fes1513	0,707571	0,000005	0,707595	0,707587	0,707577	0,707585
Fes1527	0,707519	0,000005	0,707543	0,707535	0,707525	0,707533
Fes1545-A	0,707270	0,000005	0,707294	0,707286	0,707276	0,707284
Fes1552	0,707372	0,000005	0,707396	0,707388	0,707378	0,707386
Fes1560	0,707358	0,000005	0,707382	0,707374	0,707364	0,707372
USGS EN-1	0,709159	0,000005	0,709183	0,709175	0,709165	0,709173
NIST NBS 987	0,710231	0,000005	0,710247	0,710221	0,710237	0,710245
Kar1528-B	0,707339	0,000006	0,707355	0,707329	0,707345	0,707353
Kar1526	0,707401	0,000005	0,707417	0,707391	0,707407	0,707415
Fes1556-A	0,707309	0,000006	0,707325	0,707299	0,707315	0,707323
Kar1521	0,707448	0,000005	0,707464	0,707438	0,707454	0,707462
Kar1515	0,707332	0,000005	0,707348	0,707322	0,707338	0,707346
Fes1564-A	0,707394	0,000005	0,707410	0,707384	0,707400	0,707408
USGS EN-1	0,709185	0,000005	0,709201	0,709175	0,709191	0,709199
NIST NBS 987	0,710236	0,000005	0,710247	0,710249	0,710242	0,710250
Kar1518-A	0,707626	0,000006	0,707637	0,707639	0,707632	0,707640
Fes1503-A	0,707658	0,000005	0,707669	0,707671	0,707664	0,707672
Kar1520-A	0,707462	0,000005	0,707473	0,707475	0,707468	0,707476
Kar1505-B	0,707472	0,000005	0,707483	0,707485	0,707478	0,707486
USGS EN-1	0,709162	0,000005	0,709173	0,709175	0,709168	0,709176

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Standards	Value McArthur	Mean Value Bochum	± 2 s standard error	± 2 s standard diviation	number of repetitions [n]
NIST NBS 987	0,710247	0,710241	0,000002	0,000032	359
USGS EN-1	0,709175	0,709160	0,000002	0,000030	319

sample name or number	$^{87}\text{Sr}/^{86}\text{Sr}$ measured	± 2 s mean	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: NBS 987 value McArthur and NBS 987 measured with sample	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: USGS EN-1 value McArthur and USGS EN-1 measured with sample	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: NBS 987 value McArthur and NBS 987 Bochum mean value	$^{87}\text{Sr}/^{86}\text{Sr}$ sample corrected to difference: USGS EN-1 value McArthur and USGS EN-1 Bochum mean value
NIST NBS 987	0,710253	0,000005	0,710247	0,710278	0,710259	0,710268
Kar 1530	0,707281	0,000005	0,707275	0,707306	0,707287	0,707296
Fes 1522-A	0,707481	0,000008	0,707475	0,707506	0,707487	0,707496
Fes 1541-A	0,707287	0,000005	0,707281	0,707312	0,707293	0,707301
Fes 1511	0,707537	0,000005	0,707531	0,707562	0,707543	0,707552
Kar 1523-A	0,707473	0,000005	0,707467	0,707498	0,707479	0,707488
Fes 1573A	0,707320	0,000005	0,707314	0,707345	0,707326	0,707335
Fes 1501-A	0,707505	0,000005	0,707499	0,707530	0,707511	0,707520

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Fes 1579	0,707339	0,000006	0,707333	0,707364	0,707345	0,707354
Kar 1503-A	0,707642	0,000006	0,707636	0,707667	0,707648	0,707657
Kar 1501	0,707687	0,000005	0,707681	0,707712	0,707693	0,707702
Fes 1519	0,707495	0,000005	0,707489	0,707520	0,707501	0,707510
USGS EN-1	0,709150	0,000005	0,709144	0,709175	0,709156	0,709165