Dear Editor,
dear Reviewer,

Thank you very much for your constructive comments and suggestions. We appreciate the re-evaluation by reviewer 2, which helped us to further improve and clarify our manuscript. Below, you will find a point-by-point reply list to anonymous reviewer 2 comments, with our responses highlighted in blue and italics. Where applicable, line numbers highlighted in red indicate text passages in the marked-up version of our manuscript that were changed according to the reviewers' suggestions.

On behalf of all authors,

Andreas Eberts

Comments

Comment 1, lines 510-511 / lines 516-519

"Here it could be useful to add a reference to show another example testifying the lower capability to erosion of high-grade metamorphic rock with respect to the lower-grade rock."

> Response from authors:
> *We agree that a reference could strengthen our interpretations of higher rock erodibilities being associated with higher-grade metamorphic units. However, as shown by Moosdorf et al. (2018), erodibilities can vary significantly even among metamorphic units, which precludes a general model of higher erodibilities being associated with higher-grade metamorphic rocks. In addition, as also mentioned in our manuscript, other factors like younger, post-Mesozoic differential block motion or spatial variations of joint and fracture densities have significant effects on the recent topography. We now make it more clear, however, that this observation is most likely a local phenomenon that does not necessarily depict a general trend.*

Comment 2, lines 547-551 / lines 553-561

"It is not clear how the new detected Cham fault is discussed in term of regional pattern of deformation. Add a lines on a possible interpretation of the Cham fault kinematics in term of a strike slip fault regional regime."

> Response from authors:
> *The tectonic configuration of the southwestern Bohemian Massif during the late stages of the Variscan Orogeny is interpreted as a conjugate shear system related to N to NNW directed shortening (Wallbrecher et al., 1991; Brandmayr et al., 1995; Peterek et al., 1996; Büttner, 1999; Galadí-Enríquez et al., 2010). As shown in Figure 11 in the manuscript, NNW-SSE to N-S trending tectonic structures might have been active as (I) left-lateral strike-slip faults or (II) extensional features that are oriented subparallel to the maximum principal stress. The presence of local Carboniferous-Permian outcrops located along the northwestern segments of the Danube and Pfahl shear zones thereby suggest a former extensional basin in between the Franconian Line and the Danube Shear Zone ("Naab Trough" sensu Schröder, 1988). As these outcrops are limited to the area west of the Cham Fault, we propose an important normal faulting phase of the Cham Fault during late to early post-Variscan wrench tectonics. This interpretation fits the reported ca. NNW-SSE to N-S maximum principal stress during the late stages of the Variscan Orogeny (Wallbrecher et al., 1991; Brandmayr et al., 1995; Peterek et al., 1996; Büttner, 1999; Galadí-Enríquez et al., 2010) and is in accordance with Peterek et al. (1996), who speculated on the presence of ca. NNW-SSE to N-S oriented basin-bounding normal faults close to the eastern margin of the Bodenwöhr Trough. However, as evidenced by higher metamorphic grades and extensively exposed granites to the west of the Cham Fault (i.e., domains A2 and C2), the period in between granite emplacement at ca. 320 Ma and Carboniferous-Permian basin subsidence (i.e., the Cham Phase) must have involved a significant amount of exhumation of the block to the west of the Cham Fault. Rapid uplift and erosion of the Variscan basement are thereby evidenced by granite fragments and detrital micas in sediments of the Carboniferous-Permian basins (e.g., Welzel, 1991; Mielke, 1993; Galadí-Enríquez et al., 2009).*
>
> *In general, several stress field adjustments occurred since the late Paleozoic Variscan Orogeny in the studied area (e.g., Peterek et al., 1997), which are likely to have initiated different kinematics of the Cham Fault. Repeated phases of tectonic activity with varying kinematics are also observed for most other fault zones along the southwestern Bohemian Massif (Table 2 in manuscript). We clarified the kinematics of the Cham Fault during late to early post-Variscan wrench tectonics in the manuscript and slightly adjusted Figure 11.*

Comment 3, lines 580-584 / lines 601-611

"in the text the authors said that samples from the western block have experienced a greater sedimentary burial with respect to the sample from eastern block. I do not understand why the western AFT ages could result older than eastern ones that in turn should not be covered nor reset during Jurassic. The younger ages from eastern side suggest me a greater amount of sedimentary cover over the eastern block and subsequent reset during Jurassic and late Cretaceous (also if thermal modeling show a little reheating).
The fact that Cham fault played a role in the Mesozoic basin subsidence sounds correct. This is probably the more solid evidence of Cham effect on the AFT age distribution, considering also that authors highlight that final stage of exhumation occurred in Cenozoic for both the blocks."

Response from authors:

AFT ages to the west of the Cham Fault are interpreted to record post-Variscan cooling ages (ca. 270 Ma) that were only partially reset during late Permian to Mesozoic burial (up to ca. 1400 m), thus representing mixed ages (Vercoutere, 1994). In contrast, no evidence exists for a significant sedimentary cover during the Permian to Mesozoic for the southeastern Bavarian Forest, neither from thermochronological (Vamvaka et al., 2014) nor geological data (Meyer, 1989). Instead, at least until the Early Jurassic, the southeastern part of the study area is rather interpreted as a topographic high that delivered clastic input into the adjacent Mesozoic basin to the northwest (Meyer, 1989). In the Middle Jurassic, the sea might have been able to transgress also into the central part of the study area (Meyer, 1989). However, there is no evidence that a thicker sedimentary succession formed towards the east of the Cham Fault compared to the west, where sedimentation started much earlier. During the Early Cretaceous, inversion tectonics resulted in the complete erosion of the sedimentary cover in the central and southeastern parts of the study area, as evidenced by Upper Cretaceous sediments on top of the crystalline basement (e.g., at the Grub locality, Wilmsen et al., 2010; Meyer, 1989).

The younger AFT ages to the east of the Cham Fault could thereby be explained by enhanced exhumation due to Late Cretaceous inversion tectonics (e.g., Kley and Voigt, 2008; Voigt et al., 2021). As evidenced by the thermochronological record, thrusting of basement blocks led to km-scale exhumation of numerous basement domains in Central Europe during this time (von Eynatten et al., 2021). The generally higher elevation to the east of the Cham Fault might be a remnant of this tectonic impulse. In addition, the NW-SE increasing thicknesses of Upper Cretaceous sediments in the "Regensburg-Straubing Trough" in front of the Danube Shear Zone (Führer, 1978; Unger and Risch, 1991) imply a more intense reactivation of the southeastern segment of the Danube Shear Zone. This also supports an enhanced Late Cretaceous exhumation of the adjacent area to the north of this fault segment (i.e., domains A1, B, and C1). If we assume only an insignificant sedimentary cover during the Late Cretaceous in the study area ($\ll$1 km), subsequent vertical displacement along the Cham Fault must have been greater than 1 km (Vamvaka et al., 2014) and was probably in the range of 1.5 to 2 km. We extended the paragraph on the FT age interpretation to clarify our interpretation.

Comment 4

"the correlation of AFT age and elevation has to be seen in sampling profile as vertical as possible. When sampling follow tens of km long profile, age-elevation correlation is not always expected, because of the change in topography between the center of the massif with respect to the edges. In these cases the center can record younger age at higher elevation, common pattern of slow eroding old orogens."

Response from authors:

We agree that a large lateral spacing between AFT samples makes it more difficult to reveal a relationship between ages and elevation. However, although lateral distances are small for data taken in the area of the Naab Mountains in domain C2, no distinct correlation between age and elevation is observed here (Vercoutere, 1994).

Comment 5

"I am not sure in the correct use of capitalized letter for the informal chronological terms such as early, middle and late. Please check at the: https://stratigraphy.org/guide/defs."

Response from authors:

In fact, the terms "early, middle, and late" are just as formal as "lower, middle, and upper", at least if used in the correct way. In contrast to "lower, middle, and upper", which are used to describe chronostratigraphic units (i.e., "time-rock units", eonothems/erathems/systems/series/stages), "early, middle, and late" are used to describe geochronological units (i.e., "time units", eons/eras/periods/epochs/ages). For more details on the correct usage of these terms, please see the work of Zalasiewicz et al. (2013). Hence, if used in the correct way, capitalization follows the same rules for both "early, middle, and late" and "lower, middle, and upper" (c.f., "Geologic Time Scale" of the GSA, Walker et al., 2013). We double-checked the correct usage of capitalized letters for the above-mentioned terms.

References

Brandmayr, M., Dallmeyer, R. D., Handler, R., and Wallbrecher, E.: Conjugate shear zones in the Southern Bohemian Massif (Austria): implications for Variscan and Alpine tectonothermal activity, Tectonophysics, 248, 97–116, https://doi.org/10.1016/0040-1951(95)00003-6, 1995.

Büttner, S. H.: The geometric evolution of structures in granite during continuous deformation from magmatic to solid-state conditions: an example from the central European Variscan Belt, American Mineral., 84, 1781–1792, https://doi.org/10.2138/am-1999-11-1207, 1999.

Führer, F. X.: Die Anomalien der Schwere am Südwest-Rand des Bayerischen Waldes und ihre Interpretation, Int. J. Earth Sci. (Geol. Rundsch.), 67, 1078–1096, https://doi.org/10.1007/BF01983255, 1978.

Galadí-Enríquez, E., Dörr, W., Zulauf, G., Galindo-Zaldívar, J., Heidelbach, F., and Rohrmüller, J.: Variscan deformation phases in the southwestern Bohemian Massif: new constraints from sheared granitoids, Z. dt. Ges. Geowiss., 161, 1–23, https://doi.org/10.1127/1860-1804/2010/0161-0001, 2010.

Galadí-Enríquez, E., Kroemer, E., Loth, G., Pürner, T., Raum, G., Teipel, U., and Rohrmüller, J.: Erdgeschichte des Oberpfälzer Waldes: Geologischer Bau, Gesteine, Sehenswürdigkeiten, Erläuterungen zur Geologischen Karte des Oberpfälzer Waldes, Augsburg, 2009.

Kley, J. and Voigt, T.: Late Cretaceous intraplate thrusting in central Europe: Effect of Africa-Iberia-Europe convergence, not Alpine collision, Geology, 36, 839–842, https://doi.org/10.1130/G24930A.1, 2008.

Meyer, R. K. F.: Die Entwicklung der Pfahl-Störungszone und des Bodenwöhrer Halbgrabens auf Blatt Wackersdorf, Erlanger geol. Abh., 117, 1–24, 1989.

Mielke, H.: Geologische Entwicklung des Kristallins, in: Erl. Geol. Kt. Bayern 1:25.000, Bl. 6639 Wackersdorf, edited by: Meyer, R. K. F. and Mielke, H., 10–12, 1993.

Moosdorf, N., Cohen, S., and Hagke, C. von: A global erodibility index to represent sediment production potential of different rock types, Applied Geography, 101, 36–44, https://doi.org/10.1016/j.apgeog.2018.10.010, 2018.

Peterek, A., Rauche, H., Schröder, B., Franzke, H.-J., Bankwitz, P., and Bankwitz, E.: The late- and post-Variscan tectonic evolution of the Western Border fault zone of the Bohemian massif (WBZ), Int. J. Earth Sci. (Geol. Rundsch.), 86, 191–202, https://doi.org/10.1007/s005310050131, 1997.

Peterek, A., Schröder, B., and Menzel, D.: Zur postvariszischen Krustenentwicklung des Naabgebirges und seines Rahmens, Z. geol. Wiss., 24, 293–304, 1996.

Schröder, B.: Outline of the Permo-Carboniferous basins at the western margin of the Bohemian Massif, Z. geol. Wiss., 16, 993–1001, 1988.

Unger, H. J. and Risch, H.: Die Thermalwasserbohrung Straubing Th 1 und ihr geologischer Rahmen, Geol. Jb., A, 3–51, 1991.

Vamvaka, A., Siebel, W., Chen, F., and Rohrmüller, J.: Apatite fission-track dating and low-temperature history of the Bavarian Forest (southern Bohemian Massif), Int. J. Earth Sci. (Geol. Rundsch.), 103, 103–119, https://doi.org/10.1007/s00531-013-0945-x, 2014.

Vercoutere, C.: The Thermotectonic History of the Brabant Massif (Belgium) and the Naab Basement (Germany): an Apatite Fission Track Analysis, PhD thesis, Faculteit Wetenschappen, Universiteit Gent, Gent, 1994.

Voigt, T., Kley, J., and Voigt, S.: Dawn and dusk of Late Cretaceous basin inversion in central Europe, Solid Earth, 12, 1443–1471, https://doi.org/10.5194/se-12-1443-2021, 2021.

von Eynatten, H., Kley, J., Dunkl, I., Hoffmann, V.-E., and Simon, A.: Late Cretaceous to Paleogene exhumation in central Europe – localized inversion vs. large-scale domal uplift, Solid Earth, 12, 935–958, https://doi.org/10.5194/se-12-935-2021, 2021.

Walker, J. D., Geissman, J. W., Bowring, S. A., and Babcock, L. E.: The Geological Society of America Geologic Time Scale, Geol. Soc. Am. Bull., 125, 259–272, https://doi.org/10.1130/B30712.1, 2013.

Wallbrecher, V. E., Dallmeyer, R. D., Brandmayr, M., Handler, R., Maderbacher, F., and Platzer, R.: Kinematik und Alter der Blattverschiebungszonen in der südlichen Böhmischen Masse, in: Arbeitstagung Geol. B.-A., edited by: Gattiner, T. E. and Roetzel, R., Verlag d. Geologischen Bundesanstalt, 1991.

Welzel, B.: Die Bedeutung von K-/Ar-Abkühlaltern an detritischen Muskoviten fur die Rekonstruktion tektonometamorpher Einheiten im orogenen Liefergebiet - ein Beitrag zur Frage der variskischen Krustenentwicklung in der Böhmischen Masse, Göttinger Arb. Geol. Paläont., 1991.

Wilmsen, M., Niebuhr, B., Chellouche, P., Pürner, T., and Kling, M.: Facies pattern and sea-level dynamics of the early Late Cretaceous transgression: a case study from the lower Danubian Cretaceous Group (Bavaria, southern Germany), Facies, 56, 483–507, https://doi.org/10.1007/s10347-010-0224-2, 2010.

Zalasiewicz, J., Bianca Cita, M., Hilgen, F., Pratt, B. R., Strasser, A., Thierry, J., and Weissert, H.: Chronostratigraphy and geochronology: A proposed realignment, GSA Today, 23, 4–8, https://doi.org/10.1130/GSATG160A.1, 2013.