Early Cenozoic Listwaenite Formation at a Major Extensional Fault Zone of the Oman Mountains (Fanja Area) – Insights from Structural Analysis and U-Pb Carbonate Dating*

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Abstract

Listwaenites are carbonatized and/or silicified serpentinite rocks. These rocks are common in the Fanja area (~50 km to the SW of Muscat) and typically associated with or near the structural base of the Semail Ophiolite at major extensional faults. The listwaenite forms largely unfolded, tabular bodies with thicknesses of several meters to tens of meters and lengths of a few meters to a few kilometers. Ophiolite obduction onto the Arabian margin and platform ensued to the SW during the Late Cretaceous during the Arabia-Eurasia convergence. During obduction, the Arabian margin descended into a subduction zone and was eventually rapidly exhumed, forming the initial Saih Hatat Dome. Obduction was followed by major top-to-the-NE extension until the Paleocene/Eocene transition (Stage I; Grobe et al., 2019, their Fig. 12). During this event, the initial Jabal Akhdar Dome formed. The northern margins of the Jabal Akhdar and Saih Hatat domes are flanked by a major fault zone with a throw of few to several kilometers (Frontal Range Fault, Mattern and Scharf, 2018). The activity of this fault zone ensued immediately after obduction of the ophiolite (Stage I) and again during the Late Eocene to Miocene (Stage II; Hansman et al., 2017; Mattern and Scharf, 2018). The origin of the listwaenite is debated. It either formed within the subduction zone during Late Cretaceous obduction (Falk and Kelemen, 2015) or after obduction along extensional faults in the cause of orogenic collapse (e.g., Wilde et al., 2002; Mattern and Scharf, 2018; Bailey et al., 2019). Our structural investigations revealed that listwaenite remained unfolded. This contrasts with what is expected within a subduction zone. At one outcrop, a 15 m long and 5 m wide listwaenite body is brittlely to ductilely deformed. Furthermore, listwaenite may form injections into the post-obductional latest Cretaceous Al-Khod Formation near Fanja along the Frontal Range Fault. Thus, the listwaenite is post-obductional in age. However, it is unclear if the listwaenite formed during Stage I or II along the Frontal Range Fault. For verification we performed U-Pb dating using the LA-SF-ICPMS (e.g., Woodhead and Petrus, 2019) on carbonate veins within the listwaenite. Veins with a thickness of ≤0.5 cm are common within the listwaenite. These veins form a complex network. We interpret the veins to have formed during
the final stage of the listwaenite formation because these veins appear undeformed. Two U-Pb dated carbonate veins within the listwaenite near Fanja yielded an age of 55±4 Ma. Thus, the listwaenite formed during Stage I of the Frontal Range Fault activity. Furthermore, the direction of Sigma 3 at this site was NNE-SSW which agrees with the post-obductional extensional stress field at other parts of northeastern Oman (e.g., Grobe et al., 2019).

References Cited


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Introduction

Listwaenite is an ultramafic dike-aquifer system with carbonate veins that form in the hydrous, sub-solidus stage of extensional basins. The Fanja area in the eastern Oman Mountains is a well-documented setting for listwaenite formation. The authors studied the structural and age control of the listwaenite formation in the Fanja area to understand its geological significance.

Structural investigations/observations

For structural investigations, the authors used a combination of field observations, radiometric dating, and U-Pb carbonate dating. The listwaenite is associated with extensional shear zones, and it formed in the hydrous, sub-solidus stage of extensional basins.

U-Pb dating of carbonate veins

The U-Pb carbonate dating of the carbonate veins within the listwaenite provides a minimum age for the listwaenite formation. The authors used a combination of U-Pb dating and Pb isotopes to determine the age of the listwaenite formation.

Conclusion

The key findings of the study are:
1. Field investigations revealed that the listwaenite formation is widespread and not restricted to certain locations.
2. The listwaenite is associated with the beginning of major regional extensional events.
3. Listwaenite formation is a process that occurs in a variety of tectonic settings, including extensional basins.

References

Scharf, A., 2018. White box outlines Figure 2.

Figure 1. Complex vein pattern in the listwaenite. Most of the veins are sub-horizontal and form an interconnected network. The thickness of the veins varies from a few millimeters to a few centimeters.

Figure 2. Geological map of the Fanja area between the Jabal Akhdar Dome/Nakhl Subdome (left) and Saih Hatat Dome (right) after Scharf et al. (2019). The listwaenite is always associated with these two extensional shear zones.

Figure 3. Map showing the location of the Fanja area in the eastern Oman Mountains. The listwaenite formation is indicated by the black area.

Figure 4. Absolute U-Pb dating of calcite veins in listwaenite provides a minimum age for the listwaenite formation. The age is close to the Paleocene/Eocene boundary.

Figure 5. Geometric relationships between the listwaenite and the surrounding rocks. The listwaenite is sandwiched between the serpentinite and the surrounding carbonate rocks.

Figure 6. Detailed thin section photograph of the listwaenite injection (black) and the surrounding carbonate rocks (white). The thickness of the veins varies from a few millimeters to a few centimeters.

Figure 7. U-Pb isochron diagram for the carbonate veins within the listwaenite. The age is close to the Paleocene/Eocene boundary.