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Novel data, methods and applications in Geomorphometry

Remote sensing and geomorphometry application in riverscapes evolution in the south-eastern Arabian Peninsula (Sultanate of Oman)

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1. Introduction and main goals

- Riverscapes in **arid** and **semi-arid** environments are crucial archives → understanding the landscape evolution and the active and fossil **geomorphological processes**
- Such environmental contexts are generally wide, and these settings are routinely investigated with remote sensing tools
- We selected two distinct study areas (Fig. 1) from the south-eastern margin of the Arabian Peninsula (Sultanate of Oman) to **detect climate and tectonic imprints over landform development**
- The **extant landscapes** of both regions: characterized by a network of narrow and deep **canyons** that incised limestone massifs, while the surrounding plain areas show the development of important **alluvial fan systems**

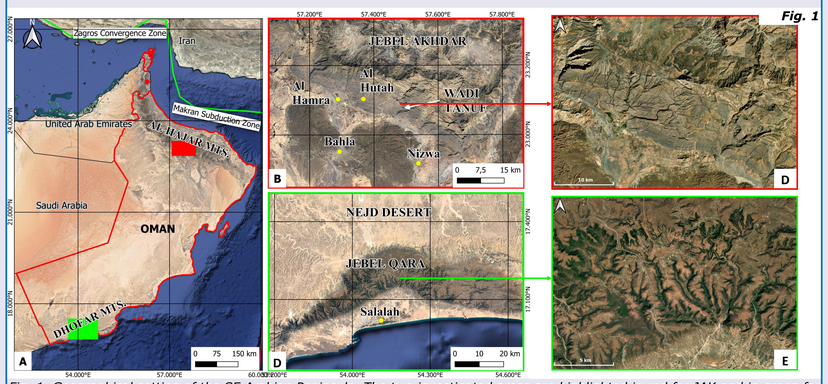


Fig. 1. Geographical setting of the SE Arabian Peninsula. The two investigated areas are highlighted in red for JAK and in green for JQA.

2. Multidisciplinary approach

- **Remote sensing**
- **Field survey**
- **Geomorphometry** (QGIS, TopoToolbox, TAK) (Schwanghart & Scherler, 2014; Forte & Whipple, 2014)
  - Normalized channel steepness index (Ksn)
  - Knickpoint detection and classification
  - Drainage divide stability (χ-mapping)

3. Remote sensing

- Analysis and processing of optical and multispectral satellite imagery
- Combination with field survey allows multi-scale analysis (Fig. 2 & 3)
  - Structural elements and landforms
  - Karst landforms and features
  - Fluvial deposits and landforms
  - Gravitative deposits and landforms
  - Anthropic landforms

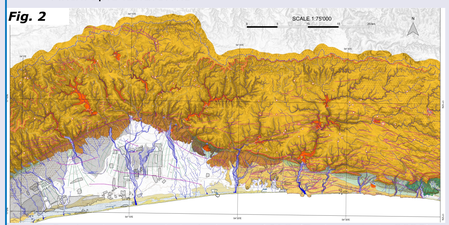


Fig. 2. Regional geomorphological map of JAQ (Zerboni et al., 2020).

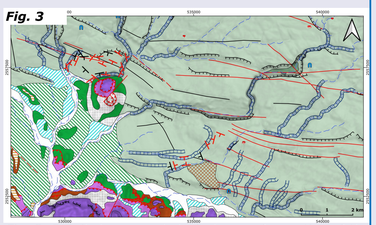


Fig. 3. Detailed geomorphological map of a portion of the southern flank of JAK.

4. Field survey

- The remote recognized landforms has been validated through field survey
- The dominant geomorphological features are represented by elements and landforms related to **structural setting, fluvial activity, and karst processes** (Fig. 4)

Fig. 4. Landforms from JAK and JQA. (A) Erosional escarpment. (B) Counterslope along a dextral transcurrent fault. (C) Wadi flowing in a canyon. (D) Limestone bedding outcropping in a canyon. (E) Fluvial terrace showing bedded gravel. (F) Karst blind valley. (G) Tufa dam and backfill. (H) Entrance of a sinkhole.

5. Geomorphometry

5.1. Jebel Akhdar (JAK)

- **Al-Hajar Mountains** (Northern Sultanate of Oman)
- Characterising the **NE-Arabian Plate** (Fig. 5)
- **Complex tectonic history**
- Pre-Cambrian sedimentary succession (**terrigenous, volcanic, volcaniclastic rocks**) followed by Permo-Mesozoic **shallow-water carbonates**
- **Ksn** values increase towards the limestone flanks of JAK but decrease in tectonic windows (Fig. 6)
- **Knickpoint** are related to changes in Ksn values and mainly controlled by litho-structural setting (Fig. 6 & 7)
- **χ-mapping** highlights the direction of drainage migration is towards South (Fig. 8)

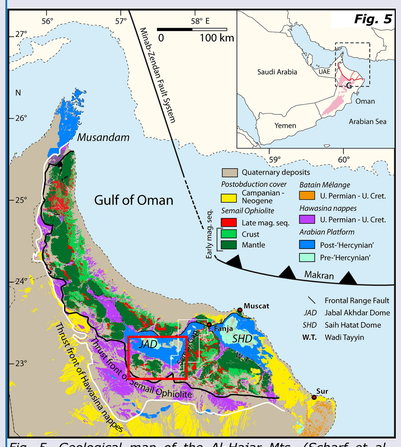


Fig. 5. Geological map of the Al-Hajar Mts. (Scharf et al., 2019). The red rectangle highlights the investigated area.

5.2. Jebel Qara (JQA)

- **Dhofar Mountains** (Southern Sultanate of Oman)
- **Transtensional faults and tectonic regime** (Oligocene – Quaternary)
- Late Cretaceous-Neogene **limestone** in contact with Pre-Cambrian **metamorphic basement** (Fig. 9)
- Stepped escarpments
- **Ksn** values increase towards the southern escarpment of JQA. In the northern area the values decrease towards North (Fig. 10)
- **Knickpoint** are mainly related to elevated values in Ksn and controlled mostly by the presence of tufa dams (Fig. 10 & 11)
- **χ-mapping** highlights the direction of drainage migration is towards North (Fig. 12)

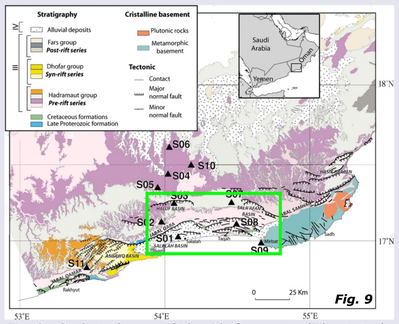
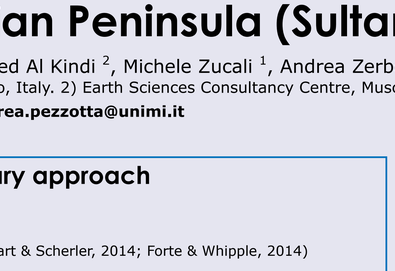
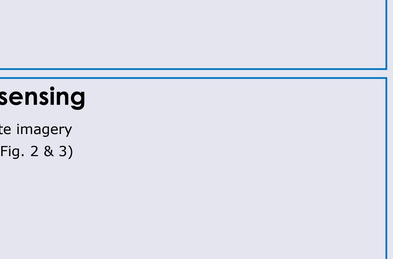


Fig. 9. Geological map of the Dhofar region (Tiberi et al., 2007). The green rectangle highlights the investigated area.





6. Conclusions

- **Field work** permits the validation of remote recognized geomorphological features, assessing the structural influence on **drainage and karstic network development**
- The **combination** of remote sensing and morphometrical analyses **quantify** the central role of **litho-structural** influence on the evolution of riverscapes in the south-eastern Arabian Peninsula (Fig. 13 & 14)
- This approach facilitates the identification of the **primary geomorphological processes** that have shaped the landscape in **arid and semi-arid contexts** of the Sultanate of Oman, making it a versatile method that can be applied to understand the riverscapes evolution processes in **analogous regions**

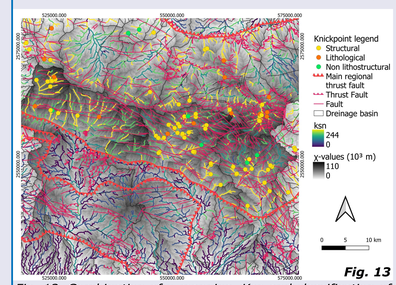


Fig. 13. Combination of χ-mapping, Ksn and classification of knickpoint and their relationships with the main structures in JAK.

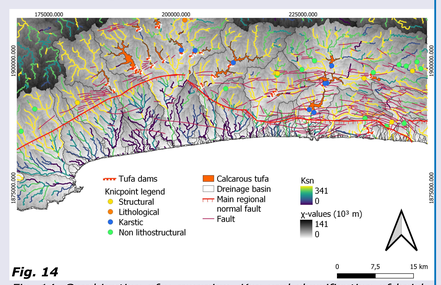


Fig. 14. Combination of χ-mapping, Ksn and classification of knick-point and their relationships with the calcareuos tufa and tufa dams and the main structures in JQA.

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