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Smooth Rock Surfaces and Streaks atop the Towers of Areu (Haute-Savoie, France): Tectonic or Snow-Glacial Genesis

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Abstract In the Haute-Savoie region of the French Pre-Alps, a meticulously designed experimental setup has yielded compelling evidence regarding the origins of polished and striated rocks found in a rather unanticipated context. Contrary to the initial hypothesis attributing these geological features to tectonic thrusting effects, typically manifested as fault mirrors exposed through erosion, the study reveals a different causative factor. It demonstrates that the annual movement of a firn, a type of perennial snowpack, is primarily responsible for the formation of these geological characteristics. This finding not only challenges conventional understandings in the field but also underscores the dynamic and often complex geological processes shaping the Earth's surface.

Index Terms polished rocks, striated rocks, firn movement, Areu, Haute-Savoie, France.

I. Summary

The polished and grooved rock outcrops found atop the Areu Towers in Haute-Savoie, France, raised questions about their origin, given the unusual location for such geological processes. Through a straightforward experiment, it was determined that the phenomenon resulted from the annual movement of transformed snow (névé) carrying pebbles during the melting process. The possibility of a tectonic origin, such as a fault plane mirror exposed by erosion, was excluded.

II. Introduction

In the span of the 1980s-1990s, we authored multiple volumes of a climbing guide dedicated to the Bornes Massif, situated within the northern subalpine ranges between Lake Annecy and the Arve valley. The fourth and final volume of the series encompassed the Aravis chain sector, leading us to explore Pointe d'Areu (2478 m) and the eponymous towers (2097 m) at the NE end of the range, commanding views over the Arve and Sallanches valley from an elevation of over 1500 m (refer to Figure 1).

During the ascent of one of the Areu Towers in October 1986, we noted the presence of massive light limestones at the summit, exhibiting polished and striated outcrops. Given their location and altitude (2080 m), an origin attributed to the Arve glacier, which existed 15 to 20,000 years ago, was ruled out. Even considering the likelihood that these streaks would have eroded over time, the widening of the valley at this location, coupled with the diffluence of Arly toward Mégève and Isère, diminished the glacier's thickness.

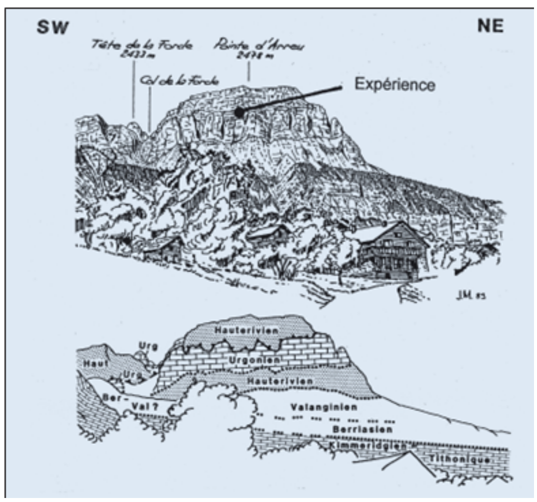

Figure 1: Sketch and geological interpretation of the Areu Towers region. View of the eastern slope of the Aravis range, from elevation 790 m (above the hamlet of Provence). Geological interpretation:"Lemanic Switzerland and Chablais" mod.

Additionally, the absence of a feeding cirque, as depicted in Figure 1, did not support the hypothesis of a local glacier. This left a tectonic origin, with students from the Geology department at the University of Geneva, including [1] proposing that the effects of sliding and loading were revealed by erosion

Figure 2: Aerial view of the Areu Towers wall. Top right, Pointe d'Areu (2478 m). On the left, the Col de la Forcle (2433 m)

III. Geological Setting

The sedimentary cover of the Bornes Massif, which experienced relatively minor displacement during the Alpine orogeny, underwent substantial deformations starting from the Oligocene period. The Aravis chain serves as the eastern boundary of the syncline [2], [3].

contributing to its Landscape Asymmetry

imposing escarpments of over 1000 m dominate the Arve valley (ESE), while the opposite slope (WNW) exhibits more gradual and consistent slopes. Thrusting impacts the northern part of the range, resulting in the fragmentation of rock bars within the landscape. For Swiss geologists, this region is where the Morcles aquifer reaches its termination.

The walls of the Tours d'Areu consist of Barremian limestone (Urgonian facies), standing at an impressive height of 180 to 200 m. These formations oversee the steep, grassy slopes of the Hauterivien (siliceous limestone). Serving as the focal point for climbing routes, these walls are surmounted by a thin, incomplete cover from the Upper Cretaceous, exhibiting diverse facies. Moreover, in an anomalous juxtaposition (overlapping), they are once again bordered by the Hauterivian and the Barremian. The latter strata also constitute the summit of Pointe d'Areu (Figure 2 for the geological interpretation) [4].

IV. Experimental Procedure

As previously indicated, the observation of polished and striated limestone outcrops in October 1986 led us to consider a glacial origin. Since this hypothesis faced skepticism from certain geologists, we opted to conduct an experiment by affixing a metal plate to one of the identified locations. The choice of lead was deliberate – firstly, its surface oxidation renders it minimally susceptible to meteorological influences, and secondly, its malleability makes it highly responsive to mechanical interactions, such as chiseling.

On July 13, 1988, we securely fastened a 3 mm thick, 9 cm by 15 cm lead plate using two expansion eyebolts. The plate's surface was intentionally left perfectly smooth. We selected a discreet location to minimize any potential interference from the infrequent rock climbers who traverse these walls.

Figure 3: The lead plate as it appeared when it was removed, after 7 years on the limestone. The streaks are clearly visible. At the top right, the arrow, 1 cm long, gives the direction of snow creep.

Control visits are carried out on October 16 fromthe same year (nothing to report!), June 21, 1989, August 14, 1991 (small lines were observed), then July 6, 1994: numerous traces were then engraved in the lead. The plaque was removed on July 27, 1995. During the last three visits, we had each time noticed that gravel covered the plaque and the surrounding rocks [5].

During checks on dates when the snow was still too abundant to allow access to the experimental device (May or June), we noted the presence of blocks of snow during the descent from the steep slopes which dominated in direction of the corridors separating the towers. These bottlenecks forced the blocks to deform, to break, then to overlap. This snow, already transformed, approximately 1 to 2 m thick,had collected not only on the surface, but also torn off and then incorporated into its underside, a quantity of rock debris of varying sizes (from mm to dm). And it is during this annual crawl, during the melting period, that the objects caught in the lower layer, often transformed into ice by alternating freeze-thaws, smoothed or etched the rock surface. It is then the most angular and siliceous rock fragments which do most of this work. These elements therefore had a good time streaking our lead plate, which is softer than the Urgonian limestone (Figure 3).

V. Conclusion

In conclusion, our straightforward experiment successfully explained the origin of streaks and the polishing observed on the rock. As depicted in Figure 2, over the span of seven years (or seven snowmelt cycles), numerous streaks have emerged. With the exception of one oblique streak, all others run parallel to the contour of the snowfield in this specific location. Similar to glacial-origin striations, these streaks commence or conclude gradually, influenced by the movements of the "hand" guiding the tools, their stability within the ice (or icy snow), and the potential blunting of rock fragments.

It is crucial to exercise caution in attributing morphologies of this nature to glacial action, as a snowfield in the vicinity of a possibly vanished glacier can equally account for the phenomenon. Therefore, these striated rocks are a product of ongoing processes, unfolding right before our eyes and within our time frame, with no involvement of tectonics in this scenario.

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