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Isotopic and Geochemical Signatures of Proglacial Lakes at Lions Rump (King George Island, Antarctica): Identifying Hydrological Sources and Assessing Chemical Composition in a Changing Polar Environment

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1. INTRODUCTION

Proglacial lakes in Antarctica, primarily fed by melting ice and snow, are sensitive indicators of climatic shifts and ongoing cryospheric and geochemical processes in their surroundings (Turner et al. 2005). Due to their shallow depth, limited water exchange, and geographic isolation, these systems are particularly vulnerable to contamination and hydrological imbalance (Bargagli 2008). Lions Rump headland (ASPA 151), located in the southwestern part of King

George Island, is a region of high ecological value with prominent glacial and limnological features. These isolated lakes not only record hydrological and chemical changes (Mulvaney et al. 2012) but also act as potential sites of contaminant accumulation, as previously demonstrated for periglacial systems in Admiralty Bay (Szopińska et al. 2018). This study, conducted on seventeen lakes in the area (water samples LR1–LR17), integrates the analysis of stable isotopes of hydrogen and oxygen with a broad spectrum of major and trace element concentrations to determine the origin of waters, mechanisms of recharge, and potential sources of chemical constituents.

2. METHODS

Isotopic analyses were carried out using cavity ring-down spectroscopy (CRDS, Picarro L2140-i), calibrated with international reference standards and normalized to the Vienna Standard Mean Ocean Water (VSMOW) scale (Skrzypek 2013). The $\delta^{2}H$ and $\delta^{18}O$ composition showed distinct spatial variability between lakes located near glacier termini and those situated further inland or at higher elevations. Some samples were characterized by depleted $\delta^{18}O$ and $\delta^{2}H$ values, indicative of a dominant glacial meltwater component, while others reflected mixing with snowmelt or atmospheric precipitation. Isotopic enrichment observed in a few lakes suggests the influence of evaporative processes. The $\delta^{2}H$ vs. $\delta^{18}O$ relationship and the position of samples relative to the local meteoric water line provided insight into recharge mechanisms and lake isolation levels (Gat 1996; Leng and Marshall 2004).

3. RESULTS

Chemical analyses were performed using ICP-OES and ICP-MS (Shimadzu 9820 and 2030), allowing quantification of major elements (Ca, Mg, Na, K, Fe, Si, P, S) and 22 trace elements, including Pb, Zn, Cu, As, Mn, Ni, Cr, Cd, and Se. The chemical composition of lake waters revealed clear spatial patterns related to glacier proximity, exposure to atmospheric deposition, and influence from wildlife activity. In most samples, lithogenic elements dominated, indicating strong interaction between water and bedrock through glacial erosion and mechanical weathering. Several lakes showed elevated levels of trace metals, potentially associated with ornithogenic input or long-range atmospheric deposition, a phenomenon also reported in freshwater of Admiralty Bay (Szopińska et al. 2018).

In some samples, increased concentrations of redox-sensitive metals such as Mn, Fe, and Al were found, especially in shallow, well-oxygenated basins, suggesting mobilization under oxidizing conditions. Slight enrichments of potentially toxic elements like Pb, As, and Zn were also noted but remained within typical Antarctic background levels. These findings highlight the need for continued monitoring of the seasonal dynamics and environmental thresholds of these aquatic ecosystems.

4. CONCLUSIONS

The integration of isotopic and geochemical data enabled the identification of water sources and the assessment of processes influencing solute composition. The results serve as a valuable reference point for further limnological studies in Antarctic proglacial zones and provide essential knowledge for conservation efforts in protected areas.

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