Atacameño communities amid the 'Lithium Rush': the relevance of geoethics and interculturality in natural sciences research

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Abstract

The Salar de Atacama (SDA) is one of the world's main sources of lithium in brine and an ancestral territory inhabited by the Atacameño, communities that have coexisted with salt lakes and salars for thousands of years. Chile's National Lithium Strategy, announced in 2023, seeks to promote the sustainable and inclusive development of this strategic industry. However, intensified mining amid water scarcity has increased socio-environmental concerns. The Anillo Project SALARES, which studies geological and microbial processes in the SDA, faces the challenge of addressing the tensions generated by scientific research in this context by adopting an intercultural and geoethical approach. This perspective recognizes the social and political impacts of research and the need to respect indigenous forms of organization, deliberation, and decision-making. To this end, the project has developed a multi-level process that includes interaction with local communities and state officials, as well as internal reflection within the research team, the latter carried out through semi-structured interviews and a questionnaire. This work systematizes these processes of dialogue and reflection. The diversity of community protocols, temporalities, and interests requires flexibility in defining research timelines, methodologies, and objectives. The

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interactions first focused on accessing the research areas and led to the signing in 2025 of an unprecedented Safeguard Protocol between one Atacameño community and the Universidad de Concepción. Two indigenous communities, based on reasonable arguments in the context of their historical demands, declined participation and denied access to part of the study area, requiring adjustments to some research objectives. The internal reflection within the research team has resulted in agreements that guide intercultural and geoethically responsible research, while highlighting the difficulties and limitations involved in doing so. Dialogue with Indigenous communities enabled progress in the alignment with community temporalities and protocols; trust-building; management of sensitive data; accessibility, usefulness of results and reciprocity; responsibility toward the context of the territory; and co-creation of knowledge, practices that fulfill the SALARES geoethical obligations. Institutional challenges, including the need for more flexible funding structures and timelines, and for the early incorporation of local communities into research design, can be concluded. This experience may contribute to future research practices in socio-environmentally complex and extractive contexts.

Keywords: *Salar de Atacama, intercultural research, Atacameño people, lithium mining, extractive contexts.*

Resumen

El Salar de Atacama (SDA) es una de las principales fuentes de salmuera de litio del mundo y un territorio ancestral habitado por comunidades Atacameñas que han coexistido con lagos salinos y salares durante miles de años. La Estrategia Nacional del Litio de Chile, anunciada en 2023, busca promover el desarrollo sustentable e inclusivo de esta industria estratégica. Sin embargo, la

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intensificación de la minería en un contexto de escasez hídrica ha incrementado las preocupaciones socio-ambientales. El Proyecto Anillo SALARES, que estudia procesos geológicos y microbianos en el SDA, enfrenta el desafío de abordar las tensiones generadas por la investigación científica en este contexto, adopotando un enfoque intercultural y geoético. Esta perspectiva reconoce los impactos sociales y políticos de la investigación y la necesidad de respetar las formas indígenas de organización, deliberación y toma de decisiones. Con este fin, el proyecto ha desarrollado un proceso multi-nivel que incluye la interacción con comunidades locales y funcionarios estatales, así como una reflexión interna dentro del equipo de investigación, siendo esta última llevada a cabo a través de entrevistas semi-estructuradas y un cuestionario. En este trabajo se sistematizan estos procesos de diálogo y reflexión. La diversidad de protocolos, temporalidades, e intereses de las comunidades requieren flexibilidad al definir el cronograma de la investigación, así como las metodologías y objetivos. Las interacciones se enfocaron primero en obtener acceso al área de estudio y llevaron a la firma de un inédito Protocolo de Resguardo el año 2025, entre una comunidad Atacameña y la Universidad de Concepción. Dos comunidades indígenas, basadas en argumentos razonables en el contexto de sus demandas históricas, declinaron participar y negaron acceso a parte del área de estudio, lo que conllevó el ajuste de algunos objetivos de investigación. La reflexión interna del equipo de investigación ha dado como resultado una serie de acuerdos que orientan una investigación intercultural y geoéticamente responsable, además de poner en relieve las dificultades y limitaciones que ello implica. El diálogo con las comunidades Indígenas permitió avanzar en la alineación con las temporalidades y los protocolos comunitarios; la construcción de confianza; el adecuado manejo de datos sensibles; la accesibilidad, la utilidad de los resultados y la reciprocidad; la responsabilidad hacia el contexto del territorio; y la co-creación de conocimiento; prácticas que cumplen con las obligaciones geoéticas de SALARES. Asimismo, se

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identifican desafíos institucionales, incluyendo la necesidad de estructuras de financiamiento y plazos más flexibles, y de incorporar tempranamente a las comunidades locales en el diseño de la investigación. Esta experiencia puede contribuir a futuras investigaciones que se desarrollen en contextos extractivos y socioambientalmente complejos.

Palabras clave: *Salar de Atacama, investigación intercultural, pueblo Atacameño, minería de litio, contextos extractivos.*

1. Introduction

Chile has one of the world's largest lithium reserves, accounting for nearly a quarter of the global total (Cabello, 2026). At national level, the highest concentration of brine-derived lithium is found in the Salar de Atacama (hereafter SDA) in the Antofagasta Region (Fig. 1). The SDA and its surrounding areas also constitute part of the ancestral territory of the Atacameño or Lickanantay people (hereafter Atacameño people), who, according to the *Corporación Nacional de Desarrollo Indígena* (National Corporation of Indigenous Development, CONADI) records, are organized into more than twenty communities within the Atacama La Grande Indigenous Development Area (*Área de Desarrollo Indígena*, ADI) and the southern zone of the Alto El Loa ADI (CONADI, 2025). These communities have coexisted with ecosystems such as salt lakes, salars, and wetlands since at least the Early Holocene (Núñez et al., 2002) and have developed water distribution systems and customary norms that remain in place today (Informe de la Comisión Verdad Histórica y Nuevo Trato, 2008).

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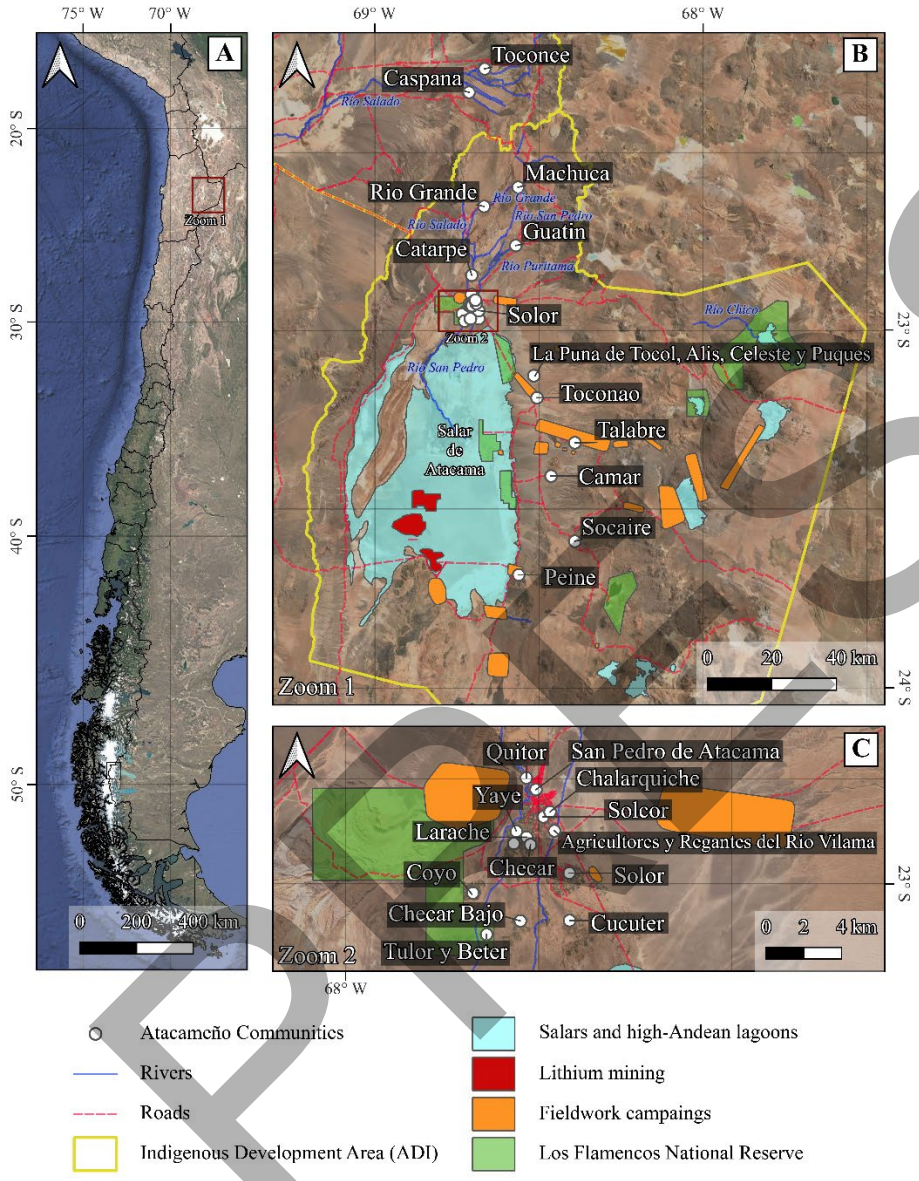

Fig. 1. A. Location of the SDA within the Chilean territory. **B.** Study area including the SDA and the high-Andean salars, as well as the distribution of Atacameño communities according to records from CONADI. **C.** Detail of the communities surrounding San Pedro de Atacama. The boundaries of the Atacama La Grande Indigenous Development Area (ADI in Spanish) are shown in yellow; field campaigns conducted between 2025 and 2026 are indicated in orange; the Los Flamencos National Reserve in green; and lithium extraction operations within the SDA in red.

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The method used to extract lithium in the SDA nowadays requires pumping large volumes of brine (saline water with high concentrations of dissolved solid elements; Munk et al., 2018), which are left in open-air evaporation ponds where the lithium is progressively concentrated (Vera et al., 2023). Two mining companies are currently active in the SDA, Albemarle (formerly Rockwood) and SQM (*Sociedad Química y Minera de Chile*); the latter has recently partnered with the National Copper Corporation (CODELCO) for lithium exploitation through 2060 within the framework of the National Lithium Strategy (Gobierno de Chile, 2024, 2025). In response to environmental concerns associated with conventional evaporative lithium extraction, alternative technologies collectively referred to as Direct Lithium Extraction (DLE) have gained increasing attention (Herrera-León, 2025). These approaches aim to recover lithium from brines through physicochemical processes that reduce or eliminate the use of large evaporation ponds (Flexer et al., 2018). However, recent assessments indicate that DLE technologies are not inherently impact free, as they may still involve substantial water and energy demands and can affect coupled brine-freshwater hydrogeological systems (Flexer et al., 2018; Vera et al., 2023).

Lithium mining has intensified the water crisis in San Pedro de Atacama and surrounding areas, a region characterized by extreme aridity and a negative water balance even in the absence of mining activities (Corenthal et al., 2016). Also, the total water availability in the system has shown a marked decline since at least 2010 onward (Liu and Agusdinata, 2020). Altogether, these processes are expected to affect flora, fauna, livelihoods, and the customs of human groups living in their ancestral lands (Flexer et al., 2018; Gutiérrez et al., 2022). This highlights the need to develop new water governance models that are based on basin-scale hydrological thresholds and effectively incorporate the perspectives and priorities of local Indigenous communities, who have expressed

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concerns about extraction models that do not recognize brine as a type of water, a resource with which they hold a spiritual connection (Barra et al., 2026).

In this context, the Anillo project *"Spatiotemporal Dynamics of Lithium in Andean Salars: Insights for Sustainable Exploration and Exploitation (SALARES)",* ANID/ANILLO/ATE240013, led by researchers from Universidad de Concepción (UdeC), aims to investigate geological and microbiological dynamics in the SDA and adjacent high-Andean salars. It was awarded funding under the 2024 Anillo program of the *Agencia Nacional de Investigación y Desarrollo* (Chilean National Agency for Research and Development, ANID), and it is a multidisciplinary initiative that brings together researchers from several institutions to investigate the processes controlling lithium formation, mobilization, and accumulation. Over a three-year period, the project integrates geological, hydrogeochemical, isotopic, microbiological, and socio-environmental approaches to develop a comprehensive understanding of lithium dynamics, with the aim of informing sustainable exploration strategies and improving the management of these fragile high-altitude ecosystems.

An intercultural perspective takes into account the ancestral knowledge of Indigenous communities, as well as their concerns and ontologies regarding the territory where research is conducted (Becerra Valdivia, 2025). It also recognizes Indigenous communities as key actors whose perspectives and consent are essential to defining research agendas. While interculturality provides a broad overarching framework, geoethics offers a discipline-specific lens that views geoscientists as active geological agents with social responsibilities, including a duty to understand and respect indigenous knowledge in their field sites (Peppoloni and Di Capua, 2015; Di Capua et al., 2017). Together, these approaches provide valuable tools to

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address the tensions surrounding knowledge production in contexts shaped by extractivism and water scarcity. Yet how geoethical and intercultural principles can be translated into the practice of interdisciplinary geoscientific research in extractive contexts and indigenous territories remains insufficiently explored, particularly in Chile. Addressing this gap is especially relevant where scientific research may have direct implications for local communities, ecosystems, and the governance of their ancestral lands.

This paper describes and analyzes the strategies the SALARES project team adopted during its first implementation phase to conduct research that is aware of its social and political impacts, open to interculturality, and committed to an ethical and responsible relationship with local communities. The paper addresses ethical and social issues at the center of scientific discussions and public debate to raise geoethical awareness and competence among research team members. It also tackles the institutional and state challenges of interacting with Atacameño communities. International law has established a renewed framework over the last 50 years under which prior and informed consultation is mandatory, and the Chilean State must address it and develop adequate public policies (International Labour Organization [ILO], 1989; United Nations, 2007). Finally, the paper seeks to contribute to the design of future research projects developed in similar contexts, where economic interests collide with longstanding territorial claims and differing perspectives on nature.

2. Contextual background on the Salar de Atacama

As noted earlier, the SDA is a conundrum: on one hand, it is a global source of lithium brine, crucial for the energy transition and addressing climate change; on the other, lithium exploration and exploitation are taking place on the ancestral territory of the Atacameño Indigenous people

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with pressing environmental concerns mainly over water scarcity. Our contribution employs a geoethical and intercultural perspective, examining a concrete academic project example that could shed light on the personal but also institutional gains, challenges and gaps of implementing such a relevant framework.

2.1. Salar de Atacama as the Ancestral territory of Atacameño people

The oases, valleys, and ravines of the SDA basin and the valley of the Loa River (Fig. 1) were first occupied around 9000 BCE by nomadic hunter-gatherers (Núñez et al., 2002). Following a major drought between 9000 and 4500 BCE, environmental stress triggered the emergence of early pastoralism, leading to the development of small hub settlements that served as bases for herding, foraging, and product exchange (Núñez et al., 2002; Informe de la Comisión Verdad Histórica y Nuevo Trato, 2008; Núñez and Santoro, 2011).

The Atacameño sociopolitical setting developed through the convergence of two cultural traditions: the high-altiplano tradition of the Upper Loa and the Arid Lands tradition of the SDA basin. Together, they shaped an emerging Atacameño Nation structured around local authorities who governed populations between the Atacama and Loa rivers. Their territorial organization relied on a mobile agropastoral settlement system, structured by a habitat constituted by mental maps that defined cultivated zones, pastures, ritual spaces, and routes of movement (Informe de la Comisión Verdad Histórica y Nuevo Trato, 2008).

The Spanish arrival profoundly altered indigenous autonomy through the imposition of the *encomienda* system since the 1540s (Trelles, 1991) and later through the policy of indigenous *reducciones* around 1570 (Núñez and Briones, 2017). Although Spanish rule attempted to redefine indigenous spatial logics through a new geopolitical order oriented toward resource extraction,

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Atacameño and Quechua communities actively negotiated these transformations, preserving and adapting their territorial practices (Durston, 1999; Gundermann et al, 2018).

Only during the 20th century the historical claims pursued by Indigenous peoples received recognition in the international arena. The 1990s marked a profound paradigm shift in international law regarding Indigenous peoples, centered on the ILO 169 Convention (ILO, 1989), which entered into force in Chile in 2009, recognizing Indigenous peoples as permanent societies with distinct identities. The new perspective was deepened in 2007 by the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP; United Nations, 2007) based on principles like autonomy, self-determination, and collective rights. It established that states have a duty to obtain the free, prior, and informed consent of Indigenous peoples before adopting legislative or administrative measures that directly impact them. Crucially, international law began to treat Indigenous peoples as political subjects rather than objects of state policy, granting them the right to control their own institutions and self-define their own destinies (Alvez-Marín et al., 2025).

Attempts to map the ancestral territories of the Atacameño people have received more criticism, even though this exercise was presented as a participatory process under new international obligations toward Indigenous peoples. In 1998, the State promoted a private consultant DATURA (DATURA Consultores, 1998), to set up a participatory mapping of the Atacameño communities by asking where ritual, ceremonial, and/or archaeological sites were; references to productive agricultural terrains; sources of surface and subterranean water systems; cattle herder paths used by the communities; and the existence of high-altitude wetlands called *bofedales* unique to the Andean region and that are considered relevant cultural landscapes (White-Nockleby et al., 2021). This very sensitive information, gathered from the Atacameño communities and presented as a way to address territorial claims, has been criticized as an act of geopiracy by Manuel Prieto

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(Prieto, 2024), using the term developed by Joel Wainwright in 2013 (Wainwright, 2013) to criticize the work of geographers' cartographic representation that aims to exercise control over territories and natural resources in the form of participatory endeavors. In 2023, the National Lithium Strategy aimed to address once again the unresolved historical land claims of the Atacameño people and mandated another report to a private consult office named Uraqi Limitada in 2023 (CONADI, 2023), led by an Aymara and with extensive experience working with Andean Indigenous communities. Nevertheless, the critique of "participatory mapping" holds if the information gathered is used to dispossess them of relevant and sensible information to gain control of the territory and natural resources, with lithium at the center, which is a "critical node" for mining.

In 2023, after 200 years of republican existence, the Chilean State for the first time inaugurated a national mining strategy that incorporates shifting international human rights standards concerning the indigenous right to prior consultation (ILO, 1989; United Nations, 2007). The National Lithium Strategy aims to expand lithium extraction and develop a domestic productive value chain through public-private partnerships with increased state involvement (Gobierno de Chile, 2023). Chile's *Corporación de Fomento de la Producción* (Chilean Economic Development Agency, Corfo) conducted two specific indigenous consultation processes in the SDA between 2023 and 2025: the first one was the distribution of accumulated benefit funds and the second one was the Codelco-SQM partnership to extend production until 2060 (Hernández, 2024).

In 2025, the government announced a public policy called "Plan de Tierras Lickanantay" to resolve historical land claims of the Indigenous communities affected by the lithium mining industries (Ministerio de Bienes Nacionales, 2025). This fits within a growing body of literature on encounters between Indigenous peoples and mining companies in postcolonial contexts (Rodon et

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al., 2024) and, more recently, on the regime governing consultation with communities about proposed extractive projects (Haslam et al., 2025).

Given this context, marked by lithium extraction and indigenous territorial claims, this work draws on two complementary approaches: geoethics, which highlights the social and environmental responsibilities of geoscientists, and interculturality, which guides how research engages with Indigenous communities. The following sections outline the methodological aims of interculturality and the paradigm shifts proposed by a geoethical framework for scientific practice.

2.2. Geoethics as a change in the Earth Science paradigm

Geoethics is defined as the "research and reflection on the values which underpin appropriate behaviors and practices, wherever human activities interact with the Earth system" (Di Capua and Peppoloni, 2019). It is a field of knowledge that articulates the Earth Sciences with humanities, serving as an intersection of geosciences, sociology, philosophy, and economics.

The Code of Ethics of the College of Geologists of Chile (CGCh), established in 1999, provides a traditional framework for regulating professional discipline and maintaining the profession's prestige (Colegio de Geólogos de Chile, 1999). It requires geologists to prioritize community health, safety, and welfare above all other interests, including those of the College or private clients (Table 1). The code emphasizes honest conduct, environmental protection, and scientific objectivity in technical reporting. Professionals must work strictly within their areas of expertise and avoid fraudulent practices and conflicts of interest. Ultimately, this code remains a vital regulatory baseline for geoscientists across Chile.

Growing human interference with the geosphere led to geoethics, reflecting the social, environmental, and political responsibilities of geoscientific knowledge (Peppoloni and Di Capua,

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2015). The founding of the International Association for Promoting Geoethics (2012) institutionalized geoethics in research, education, and decision-making. A key milestone was The Cape Town Statement on Geoethics (Di Capua et al., 2017), presented at the 2016 International Geological Congress. It establishes normative principles for sustainability, social well-being, and intergenerational justice, fostering responsible practices. The Statement frames geoscientists as an active "geological force" protecting the Earth system and urges practitioners to apply a knowledge base broader than natural sciences, incorporating social perspectives, cultural diversity, and geoheritage. Ultimately, geoethics marks a profound shift in the Anthropocene: geoscientific knowledge is no longer neutral but entails explicit responsibilities toward communities and territories (Di Capua et al., 2017).

Drafted by the Geoethics Group of the Geological Society of Chile (SGCh), coordinated by Dr. Luisa Pinto Lincoñir, and published in April 2024, the Código de Geoética de Chile (Sociedad Geológica de Chile, 2024) draws on the Cape Town Statement on Geoethics alongside Chilean professional frameworks. The SGCh code is the first of its kind (Collao Quevedo, 2026) and integrates a holistic earth-system vision emphasizing responsible resource management, research integrity, ethical training, transparent communication, and sustainable development (Table 1).

The SGCh code frames geological features not merely as resources, but as heritage with scientific, cultural, and intrinsic value, promoting "geosites" for landscape management (Sociedad Geológica de Chile, 2024). Crucially, Article 18 mandates learning from indigenous geodiversity knowledge, while Article 25 explicitly requires respecting indigenous territories, obtaining work authorization, and accounting for territorial claims. This aligns with international consultation standards under 169 ILO Convention (ILO, 1989), mandatory in Chile since 2009. In the SDA, post-2023 consultations over lithium mining expansion in Atacameño ancestral lands highlight ongoing

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tensions among community, state, and corporate actors regarding benefit-sharing (Perrone and Cotula, 2026). Applying the SGCh Code thus demands broader cultural perspectives and adherence to evolving international State obligations.

Table 1. Summary of paradigm shifts between the code of conduct developed by the CGCh in 1999 and the code of geoethics published by the SGCh in 2024.

Feature	**Code of conduct for geologists (CGCh) (1999)**	**Code of geoethics (SGCh) (2024)**
Primary focus	Professional prestige and discipline	Ethical interaction with the Earth system
Social role	Safety and welfare of the community	Active social agent and intercultural collaborator
Environment	Impact mitigation and physical protection	Geodiversity, geo-heritage, and sustainability
Indigenous rights	Not explicitly addressed; included in "society."	Explicit duty to learn from and respect indigenous knowledge and respect indigenous rights with reference to State oversight
Education	Technical improvement and professional advancement	Holistic ethical training, diversity, and social responsibility

Source: Código de Ética del Colegio de Geólogos de Chile (Colegio de Geólogos de Chile [CGCh], 1999), Código de Geoética de la Sociedad Geológica de Chile (Sociedad Geológica de Chile [SGCh], 2024).

2.3. Research from an intercultural perspective

Historically, Chilean academic research tended to objectify Indigenous communities, treating them as cases for scientific observation rather than as interlocutors (Prieto, 2024). Addressing these

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practices, the UdeC's 2022 Guidelines for Intercultural Research (Morales Ortiz et al., 2022) reframed interculturality as an ethical project dismantling colonial power asymmetry (Restrepo, 2015).

From a comparative lens, in Canada, there has been an institutional effort to develop core principles that must guide intercultural research: self-determination, which supports Indigenous peoples in setting their own research priorities; the decolonization of research, understood as respecting indigenous knowledge and supporting community-led initiatives; accountability, requiring strict adherence to indigenous ethics and protocols; and equitable access, promoting fair access for Indigenous students and researchers. This approach mandates meaningful engagement starting from the initial project planning and continuing through to the dissemination of results (Natural Sciences and Engineering Research Council of Canada, 2024).

As a normative principle, interculturality entails recognizing and respecting Indigenous peoples' own forms of organization, deliberation, and expression, which includes effective participation in decision-making processes, the translation of official documents into indigenous languages, and the incorporation of intercultural advisors in technical settings (Walsh, 2009; Rivas Palma et al., 2021). Ultimately, the intercultural lens functions as a bridge between indigenous struggles and the national policy framework, fostering an exchange of knowledge, values, and traditions (Becerra Valdivia, 2025). Here, we critically reflect on a concrete academic project focused on the sustainable exploration and exploitation of lithium in the SDA, including its interactions with Atacameño communities, and examine what it entails to conduct this work through an intercultural lens.

3. Methods and engagement approach

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We present an alternative to the conventional geological perspective on research. By treating the SDA as the ancestral territory of the Atacameño people and adopting a geoethical paradigm based on the 2024 SGCh Code, we challenge the traditional approach underpinning our research project. Our initial concerns focused on respecting local Atacameño community protocols for access to and sampling in their ancestral territory, even though ANID did not require it. The research team also aimed to foster dialogue between the knowledge, values, and lived experience of the Atacameño people and their organizations and the academic sphere. This contribution reflects the challenges faced and the achievements made towards more geoethical practices for academia. This approach has been carried out during the first two years of implementation of the project (2024 to 2026), and we will address in the next subsections the interaction processes held with Atacameño communities in the SDA, public state officials, and inside the SALARES team.

3.1. Initial dialogic community approach

The initial approach to Atacameño communities occurred only once the project was awarded in 2024. The broader context was conflict-ridden because a national public policy had expanded lithium mining in the area in 2023. We submitted formal requests for permission to access and take samples within their ancestral territories. Although most territories within the project study areas are State-owned land, Atacameño communities, as part of their ancestral territorial claims, have control of the territories involved in our research project. So, we contacted local authorities to respect local indigenous governance structures in the territories of Caspana, Toconce, Talabre, Toconao, Peine, and Socaire, as the team required access for the project's geological and biological research. In addition to the individual contacts, we established contact with the *Consejo de Pueblos Atacameños* (Atacameño Peoples Council), an association of 18 Atacameño communities within the Atacama La Grande ADI (Fig. 1).

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We used a non-probability sampling method to reach Atacameño leaders' who represented, in various roles, the Indigenous communities involved in the project. We mainly used purposive sampling, which is justified when the study involves a hard-to-reach population (Etikan et al., 2015). We communicated with different members of the Indigenous communities, including community leaders, members of specialized environmental or territorial stewardship units, and legal and scientific advisors. Rather than following a predetermined plan, we established communication through an iterative process in which initial contacts made by researchers (seeds) and graduate or undergraduate students helped identify subsequent interlocutors to approach and suggested how to proceed in each case. We also contacted Atacameño students at our home university, who, through familiar ties, helped us reach some communities. These conversations were very helpful, lasted several months, and were led by different members of the project team, depending on the needs of the various research lines involved in carrying out activities in the territory.

Where possible, dialogue was established, preferably through in-person meetings, although also online, with local actors representing Indigenous communities in order to communicate the objectives and methodologies of the project, and to explore appropriate possibilities for collaboration and/or forms of reciprocity in line with the interests of each organization.

This process, which drew on knowledge of academics and students of the study area and their personal connections with local leaders, was a heavy burden on the members of the project because its feasibility relied on interpersonal skills and the need to navigate socio-environmental conflicts over the expansion of lithium extraction in the region.

3.2. Institutional oversight

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The Chilean State required only an administrative permission to pursue the SALARES research project, even though the research area is the ancestral territory of the Atacameño people and public debate over land claims has occurred, as noted above. Therefore, in 2024 a formal request for guidance and authorization was submitted to the *Corporación Nacional Forestal* (Chile's National Forest Corporation, CONAF), a public-private agency in Chile under the Ministry of Agriculture in charge of protected areas. Through an online platform (conaf.cerofilas.gob.cl), by email and one online meeting, we obtained permission to do fieldwork in the Los Flamencos National Reserve (Fig. 1B).

To better understand what the Chilean state is doing in our project's research area, we interviewed the main public officials who oversaw indigenous consultations on lithium mining in the country. AAM and FBM interviewed, as part of the SALARES team: Leonardo Valenzuela, Member of the *Instituto Nacional de Litio y Salares* (National Institute of Lithium and Salars, ILiSa) and head of the Indigenous Consultation between the Chilean State and the Atacameño people over exploration and exploitation of Lithium (Santiago, 09-05-2025); Mauricio Solari, head of the *Corfo* local office at San Pedro de Atacama (San Pedro de Atacama, 12-05-2025); Félix Galleguillos, Regional head of CONADI (San Pedro de Atacama, 14-05-2025) public office in charge of indigenous policies in the country; Ricardo Arancibia and Victoria Ulloa, head and lawyer respectively of the Indigenous peoples section at the *Ministerio de Bienes Nacionales* (Ministry of National Assets) in charge of public land management and land regularization in the country (videocall, 27-05-2025). These conversations did not aim to produce an output but rather served to clarify the particularities of current interactions between public officials and the Atacameño communities in the SDA around policies on mining, water rights, and territorial claims over land, among other socio-legal conflicts in the area, informing the interpretation of subsequent results.

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3.3. SALARES intra-team learning curve

It was considered essential to identify common ground, as a foundation for operationalizing geoethical principles within a context of conflict, and potential differences within the project team's vision regarding the development of research that incorporates an intercultural perspective and geoethical framework, given the novelty of this approach within geosciences research.

AAM and FBM conducted semi-structured interviews beginning in April 2025, and the issues raised in them have since been revisited in several conversations during the development of the SALARES project. The aim was to discuss each researcher's prior experience working with communities and to assess the team's capacity to conduct open, flexible research that incorporates the demands and interests of the inhabitants of the SDA area, taking into account early concerns and requests expressed by the contacted communities. The interviews held with the principal investigators (PI) of the project (five people: three geologists, one biologist, and one lawyer) were based on topics related to ethical, epistemic, and governance dimensions of the SALARES project: the alignment of academic planning with communities temporalities and protocols; the necessity of trust building; the ethical management of sensitive or strategic information; the accessibility, usefulness and accountability of research outputs; responsibility toward the social and cultural context of the territory; the aim of reciprocity as a foundational principle of research practice; and finally, the co-creation of knowledge and change in researcher roles. The responses underwent transcription and thematic analysis to identify common response patterns among participants' answers (Braun and Clarke, 2006). Responses were coded, identifying instances in which each participant referred to the predefined thematic categories, despite the open and unstructured format of the discussions. Relevant excerpts were tagged accordingly, allowing the research team to subsequently assess the degree of convergence in participants' perspectives on each topic.

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In addition, an eight-question open-ended questionnaire was implemented in December 2025-January 2026 among the project's undergraduate and graduate students regarding the possibilities, challenges, and responsibilities of academia in adopting an intercultural perspective, based on their experiences. The questionnaire was informed by the same topics identified in the interviews (full questionnaire available in the Supplementary Material). In this case, a questionnaire was deemed more appropriate than conducting interviews, given the number of students involved. Moreover, because the interviews with the PIs had already been conducted and analyzed, we could formulate more targeted and specific questions. The sample comprises seven undergraduate students (one law student and six geology students), one master's student (public law), and three doctoral students (PhD in Earth Sciences). As with the interviews, a thematic analysis was conducted on the students' answers, identifying recurring points of agreement and disagreement for each question.

Following the interviews and the questionnaire, the points of agreement across both methods were synthesized, integrating the core ethical commitments guiding our research with the feasibility of implementing them in the field. The synthesis prioritized consensus to establish a shared baseline for a grounded geoethical framework that guides the SALARES project's engagement with Atacameño communities. The few divergent views that emerged across both methods concerned secondary details and were therefore not incorporated into the synthesis, so as to maintain focus on the team's operational consensus. Because the responses overlapped, we merged some of the seven guiding topics from the PIs interviews and the eight questions from the students' questionnaire.

4. SALARES research experience as a case study for geoethics

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Research in the SDA serves as an important case study in geoethics: it is a territory where intense extractive pressure from an industry of national strategic priority converges with growing scientific efforts to better understand salar dynamics and environmental impacts, alongside numerous highly organized Indigenous communities deeply committed to safeguarding their worldview and ancestral territory. This convergence was previously named as a conundrum, and it illustrates the geoscientist's transformation in conflicted socio-environmental territories. The SALARES project approached the ancestral territory of the Atacameño people as an "ethical space" for redefining intercultural academic research, in which our team held collaboration and reciprocity as foundational mandates to move beyond technical or academic extraction. During this work we faced obstacles and challenges that could be used as lessons to properly address the dynamics of scientific inquiry with Indigenous peoples. This section presents these results and discusses their implications for geoethical practice.

Some details of the interactions with the communities described in the following subsections are not disclosed out of respect for the confidentiality of the conversations held and the processes of mutual understanding and negotiation involved. These are understood as a horizontal dialogue rather than an extractive process in which the community serves merely as a source of information for us. We carefully decided to be attentive to the way in which we disclose information. Geoethical challenges from an academic perspective mean scrutinizing not only how we treat data, but also our interactions with local communities. Regarding the team's own contributions, quotations from researchers and students are presented anonymously, identified only by the role the respondent held within the SALARES team at the time of the interview or questionnaire. Participants responded on an anonymous basis so that they could speak freely about issues that

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often involve critical reflection on their own work or that of other team members. This commitment is particularly important given that some of them are no longer affiliated with the project.

4.1. Who controls access to the Salar de Atacama? Tensions during fieldwork

SALARES initially submitted its fieldwork request to Chilean state administrative offices. CONAF initially rejected access to the Flamencos National Reserve, co-managed with the Toconao community, for 2024 due to the early flamingo breeding season restricting SDA access, ranger accompaniment requirements, and research schedule closures. Subsequently, on October 22, 2024, CONAF authorized work starting in 2025, subjected to defining specific dates with reserve administration.

However, fieldwork also requires consent from Atacameño communities exercising autonomous territorial governance and independent regulations over high-Andean lagoons and salars (Fig. 1). Because each community operates under its own timelines and protocols, field scheduling requires flexibility.

The CONAF authorization is insufficient to access the territory effectively because it is not coordinated with Atacameño communities. Once granted, CONAF does not ensure that the permit fulfills its intended purpose, nor does it mediate with local communities, leaving access management to individual research projects. As a result, the ability to carry out research may be significantly constrained, despite securing funding. This situation reflects a broader limitation in current institutional frameworks, which do not fully account for the extent to which socio-environmental conflicts can restrict or even prevent the implementation of funded research projects.

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One concrete example of how the SALARES team built a rapport with the Indigenous community of Peine was a process of gradual openness and trust-building that allowed to finally sign a written document. Initial contact was established during one of the first field campaigns, when team members presented the objectives of the project's structural geology group to the community's environmental committee and received authorization to continue their work in the territory with the accompaniment of community members. These advances were somewhat delayed by a change in the community's leadership, which made it necessary, to a certain extent, to rebuild the relationship. This engagement led to the signing, in June 2026, of a protocol entitled General Guidelines for the Admission of Scientific, Research, and Academic Activities (*Lineamientos generales para el ingreso de actividades científicas, investigación, y académicas*). This document aims to regulate the ethical, territorial, and community conditions under which scientific, academic, or research activities are conducted within the Peine territory, ensuring the protection of biodiversity, genetic resources, and the associated cultural, material, and anthropological heritage. It establishes a clear and mutually agreed-upon framework for action, including the measures to be applied in the event of non-compliance, and serves as authorization to carry out one specific fieldwork campaign.

Another relevant example was the signing, in April 2025, of a written document between the Talabre community and UdeC: an unprecedented Safeguard Protocol (*Protocolo de Resguardo*). The instrument includes a specific confidentiality clause that includes the negotiation process. Through this document, the community agrees to participate in and collaborate with the SALARES research project to allow field activities within its territory. For its part, the UdeC, on behalf of the SALARES Project, commits a series of obligations aimed at safeguarding the environmental and cultural integrity of the community and its natural surroundings. The document underscores the

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importance of maintaining ongoing dialogue, mutual respect, good faith, and free and informed consent in pursuit of the community's sustainable development. The university affirms its commitment to respecting the human rights of Indigenous peoples and the community's right to withhold sensitive information. The community, in turn, recognizes the university's right to carry out activities that contribute to local development and grants authorization to access its ancestrally occupied territory, provided that such access is always accompanied by community members. The entire SALARES research team was required to complete a territorial induction workshop, led by an anthropologist, to receive, after a test, a certification of adequate knowledge of the Talabre community and the significance of the territory it inhabits.

The Atacameño communities of Caspana and Toconce (Fig. 1B), which belong to the Alto El Loa ADI and regulate access to the El Tatio Geysers, have facilitated and formalized the research team's entry through established communication channels with the geothermal park's tourist administration.

After a few months of email exchanges and remote videoconference meetings with two other Atacameño communities in the area, they refused to allow research within their territories. Their decision was based on disagreements with the project's objectives, methodologies, and proposed forms of community participation. Their refusal reflected a broader stance toward similar research initiatives, rather than a position specific to this study. Both communities emphasized that involvement in the design of the project was desirable; however, one of them expressed opposition to any initiative that might foster an intensification of mining in the SDA, even if labeled as sustainable. These refusals led on one hand to the reduction in the sampling area of our academic project and, more specifically, forced one PhD student to make time-sensitive adaptations to the methodologies and objectives of her doctoral thesis project that was already underway:

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> As access to that significant portion of the territory was not granted, it became necessary to narrow the corresponding objective and redefine the study's overall focus. This also required incorporating new methodological approaches that would allow the project to meet the standards and requirements of a doctoral thesis. (PhD student)

Furthermore, one community's refusal has prevented access to rock successions relevant to understanding the uplift of the Western Cordillera, one of the project's main geological objectives.

To geoscientists, difficulties in applying the 2024 Code of Geoethics of the SGCh lie in the scarcity of previous experiences from which to learn (Collao Quevedo, 2026). Geoethical practice is not built from a written document alone: it is constructed and sustained through a shared praxis among research groups, and through its transmission during undergraduate and graduate training. In northern Chile, where territories are seldom fenced as they are in the central-southern regions of the country, fieldwork has traditionally been carried out wherever a dirt track allowed access, except where a physical barrier or explicit private control was encountered. Under this practice, questions of land ownership and of respect for the traditions of Indigenous communities were frequently not addressed consciously. Making these long-standing assumptions explicit is part of the shift proposed by the Code, and a precondition for building the collective practice that geoethical guidelines require.

As access to the territory, inhabited and safeguarded by local communities, became limited, either permanently or through prolonged delays, the research team was required to adapt its working pace to the socio-political conditions of the area. This process involved recognizing that the scientific objectives underpinning the project may not necessarily align with the immediate interests of local inhabitants, and may even generate concern or mistrust, particularly when the

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knowledge produced is perceived as potentially contributing to the intensification of extractive activities. Such concerns are closely linked to possible impacts on key aspects of local livelihoods, including tourism and water availability. This flexibility stands in tension with the requirements of a State-funded Anillo project, which must deliver the outcomes committed at the time of award, including scientific publications and outreach activities.

4.2. SALARES team standpoints on geoethical challenges and their practical implementation

The synthesis of interviews conducted with project PIs alongside student questionnaire responses identified a shared standpoint within the team regarding geoethical challenges associated with research in the SDA region. The analysis highlighted this consensus, which the research team validated. This standpoint is articulated through internally agreed topics aimed at adapting scientific practice to an intercultural context while respecting local protocols, temporalities, and governance arrangements. Overlapping responses were merged into a final set of six geoethical topics. Additionally, for each topic, progress in community interactions was described, capturing how these geoethical considerations were operationalized beyond theoretical discussion.

4.2.1. Alignment of academic planning with community temporalities and protocols

There is strong consensus that academic planning must align with community temporalities and protocols through institutional and methodological flexibility, especially given the fragmentation of territories into several communities with distinct priorities and political tensions. The team agrees that rigid academic schedules were incompatible with community decision-making, emphasizing early dialogue, clear communication, and prior agreements on calendars, protocols, and organizational structures. Researchers must recognize that they must forgo certain areas of

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interest to focus on where access is genuinely feasible and agreed upon, and the project can develop only if the research agenda is accepted.

> It is important to establish clear and permanent channels of communication through which communities can express their own timelines and protocols, ensuring that these are realistically incorporated into the project's planning. (PhD student)

To implement these agreements, we are maintaining dialogue with the communities to explore possibilities for scientific collaboration and to reach agreements that would enable the development of research that safeguards the integrity of these Andean ecosystems while generating tangible benefits for the inhabitants of the territory. However, the administrative structure of the Anillo SALARES operates on a rigid timeline, so dialogue must begin early to plan research objectives and sampling in accordance with the communities involved. All of this happens at the expense of the academic research team, because the institutional frameworks are rigid and have no indigenous cultural accommodation. This brings an important degree of uncertainty into the research process.

Signing the fieldwork guidelines with Peine, the Safeguard Protocol with Talabre, and formalizing consensual access to the territory are important steps toward developing respectful research in the territory.

4.2.2. Trust-building between academic team and communities

Responses converge in identifying transparency, consistency between discourse and practice, and clear and accessible communication as fundamental conditions for a successful geoethical practice. A coordinated team strategy for interaction with the communities was necessary to ensure effective and unified communication, and to avoid inconsistencies or false expectations. Understanding the

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territory's social and political complexities is necessary to avoid offending local sensitivities and engage with communities appropriately. Several responses also emphasize the importance of active participation of communities in fieldwork and the value of maintaining a sustained presence in the territory.

> Fieldwork accompanied by community members fosters closer bonds and demonstrates that research is not conducted externally or imposed, but rather collaboratively and respectfully of the territory and those who inhabit it. (Undergraduate student)

One way in which the SALARES team was involved in scientific trust-building was going to fieldwork campaigns conducted in collaboration with the local environmental monitoring teams of Talabre and Peine, whose members are responsible for safeguarding their natural environment and ensuring compliance with environmental protection protocols. This trust was also built through transparency in presenting the project's objectives and methodologies, along with clear commitments to return the information collected during fieldwork to the communities.

It is necessary to underline that trust-building relationships between the academic research project and the Indigenous communities was an ongoing process depending on multiple variables that were out of reach from an academic perspective. For example, if a decision affected the availability of water already scarce, or the end of a consultation process meant to reach an unsatisfactory agreement, or even a bad experience with a previous academic team, could mean restricting permission already granted for a field trip or limiting the possibility of collaboration, or even, as was the case for SALARES, being uninvited to a community celebration based on a previous bad academic experience.

4.2.3. Ethical management of sensitive or strategic information

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With respect to the safeguarding of ancestral and local knowledge, responses overwhelmingly recognize its legitimacy and centrality. A central commitment is to communicate research information to the Atacameño communities involved before any academic publication, prioritizing their protection. This includes the review and discussion of potentially sensitive data and the joint assessment of appropriate dissemination strategies, including the possibility of restricting or omitting certain information when its publication could entail risks for communities or the territory.

> To achieve this, the project could implement data governance mechanisms that filter or anonymize sensitive information prior to its publication or submission to state agencies. (PI)

This position contrasts with a minority view that supports the unrestricted dissemination of knowledge and places the regulation of its uses beyond the project's scope of responsibility. Also, the team explicitly recognizes that, beyond a certain point, the circulation and potential uses of published academic information exceed the control of researchers, constituting a structural limitation of scientific dissemination.

In practical terms, this commitment has been operationalized by delivering a written document before each field campaign detailing planned activities and a post-field report summarizing the work conducted, followed, once available, by a more comprehensive report including analytical results.

4.2.4. Accessibility, usefulness of results, and reciprocity with communities

Responses converge on the idea that reciprocity should be defined collaboratively and conceived as a relational process integrated into the project's design, with varying emphasis on educational,

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territorial, symbolic, or political dimensions. This requires understanding and, where possible, incorporating community interests and priorities into the project's orientation. Dissemination should take formats appropriate to community objectives and capacities that are not limited to traditional academic products and should be pursued through outreach or communication activities only when explicitly requested and mutually agreed upon. There is consensus that identifying meaningful forms of reciprocity requires attentive listening without prior assumptions and avoiding the imposition of academic definitions of value. Nevertheless, the team acknowledges persistent uncertainties regarding how to reconcile academic objectives with local needs, which may not always converge.

> It is often easy to imagine reciprocity from an outsider's perspective, yet these may not serve communities or may even be perceived as disrespectful if they fail to align with their priorities. (...) the most important step is not to assume, but to ask and listen. (Undergraduate student)

In the community of Talabre, a first feedback report presenting the initial water chemistry data collected in the area was delivered to the community via email on May 5, 2025, in line with the commitment to prioritize community access to the information generated, information that had been specifically requested by the community and that they considered of great importance. These results were subsequently presented and discussed with the community on October 19, 2025. In addition, environmental monitors participated in a training workshop on microbial mats led by a researcher from the SALARES project (October 19, 2025). The activity included a lecture followed by a field-based practical session to apply the concepts discussed. This initiative responded directly to the community's expressed scientific interest in this research area.

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Several Atacameño communities include science professionals who conduct their own research in the territory, making it feasible to establish horizontal forms of collaboration in which the scientific interests of both parties are mutually enriched. For example, one of the primary interests of the *Consejo de Pueblos Atacameños* in engaging with the SALARES Project lies in scientific collaboration, insofar as the project's findings and the expertise of its researchers may be relevant to their own objectives. Similarly, there is interest in the use and greater visibility of its Chemical Water Analysis Laboratory, the first in South America to be managed by Indigenous communities.

4.2.5. Responsibility toward the social and cultural context of the territory

There is a convergence on the recognition of an ethical responsibility to understand the social, cultural, and territorial dimensions of the salars, conceived as socially and historically inhabited territories imbued with multiple meanings. Local and indigenous knowledge is widely valued as indispensable for a comprehensive understanding of the territory and, in line with this approach, the project seeks to create spaces for reciprocal knowledge exchange. Researchers have expressed a positive disposition toward receiving training in knowledge systems rooted in the communities, including their historical and contemporary social contexts, which are understood as essential for interpreting ecological processes in the SDA region. Field campaigns are expected to be carried out in the company of community members, who possess the most detailed territorial knowledge and are recognized as stewards responsible for the care and protection of the territory.

> Any research conducted within the framework of the SALARES project should acknowledge that scientific knowledge is produced within an environment where different forms of knowledge, interests, and relationships with the territory coexist. (Undergraduate student)

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By integrating local inhabitants through training and participatory monitoring, the project has the potential to transform or strengthen communities as key actors in governance, enabling them to scrutinize mining companies' environmental impact assessments with data "in hand." This, combined with the communities' deep territorial knowledge, helps ensure that the management of saline ecosystems is not driven solely by corporate interests, but instead rests on a public technical foundation that safeguards ecosystem services and strengthens communities' capacity for negotiation and territorial defense.

The presence of community members during fieldwork activities has proven deeply enriching. Many are welcoming and openly share their knowledge of the area, teaching us not only about cultural aspects but also about the natural environment, like local plants and herbs. Their guidance has also been fundamental in ensuring that fieldwork is carried out respectfully and appropriately, helping us identify places, practices, and their relationship with the land. Altogether, this relationship broadens our appreciation of the territory beyond the scope of scientific research alone.

4.2.6. Co-creation of knowledge

The team largely associates the recognition of communities as co-creators of knowledge with a significant transformation of the researcher's role, shifting from extractive practices toward collaborative, facilitative, and learning-oriented approaches. This transformation is understood to affect research design, methodologies, validation processes, and dissemination decisions. The team recognizes the potential for more symmetrical research relationships through the inclusion of community members or, where appropriate, communities as collective actors, as co-authors of joint publications. This is grounded in the fact that several Atacameño communities include

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professionals with scientific training and conducting their own research processes. From this perspective, the role of the SALARES project is not limited to delivering useful information but extends toward fostering collaborative and mutually enriching research partnerships.

> Local communities possess in-depth, situated knowledge of the territory that is essential for a comprehensive understanding of the study. Disregarding this knowledge ultimately impoverishes research. Therefore, when concerns or disagreements arise, the appropriate response is adaptation and dialogue, recognizing that no one knows the territory better than those who inhabit it. (PhD Student)

Regarding the structural geology area of the project SALARES, online meetings were held with members of the professional team of the *Consejo de Pueblos Atacameños* (meeting held on November 12, 2025), as well as with the professional geologist of the Talabre community (meeting held on November 7, 2025). These meetings addressed shared interests related to results associated with the identification of fault systems. The project team presented its specific objectives and preliminary results, while community representatives expressed interest in understanding the relationship between these structural systems and water circulation, opening avenues for collaboration aligned with shared interests and objectives. Furthermore, the communities contributed valuable knowledge regarding the identification of structural systems based on their own research and their in-depth understanding of the territory, resulting in a productive, evidence-based discussion between the project team and the communities' professional staff.

A similar engagement took place during joint fieldwork conducted with the environmental team of the Peine community, which also includes a professional geologist (joint fieldwork conducted from March 23 to 28, 2026). On this occasion, the structural geology group of the SALARES

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project visited various sectors of the Peine territory together with the community's professional team, discussing the relationships between structural systems, volcanism, and orogenesis, resulting in a fruitful relationship and exchange of knowledge. Subsequently, online coordination meetings were held to arrange a return visit to the territory, resulting in a collaborative field campaign conducted jointly with the community's professional team, during which a specific exchange of knowledge regarding the geology of the area took place.

Also, their territorial knowledge complements the information regarding water dynamics, including historical and current changes in flows and water availability, and has helped guide sampling toward relevant locations. This knowledge extended to identifying the location of springs associated with geological faults, revealing a structural control on hydrogeological circulation that would otherwise have been difficult to detect. These interactions have fostered a genuine exchange of knowledge: communities share their understanding and experience of the territory, while researchers explain the processes and methodologies underlying the sampling. Beyond its scientific contributions, this accompaniment has also enhanced the safety of field teams during fieldwork.

Figure 2 synthesizes the relationships between the methods and approaches employed and the geoethical topics addressed throughout this section, highlighting how progress in each of these topics marks a shift toward a new geoethical paradigm.

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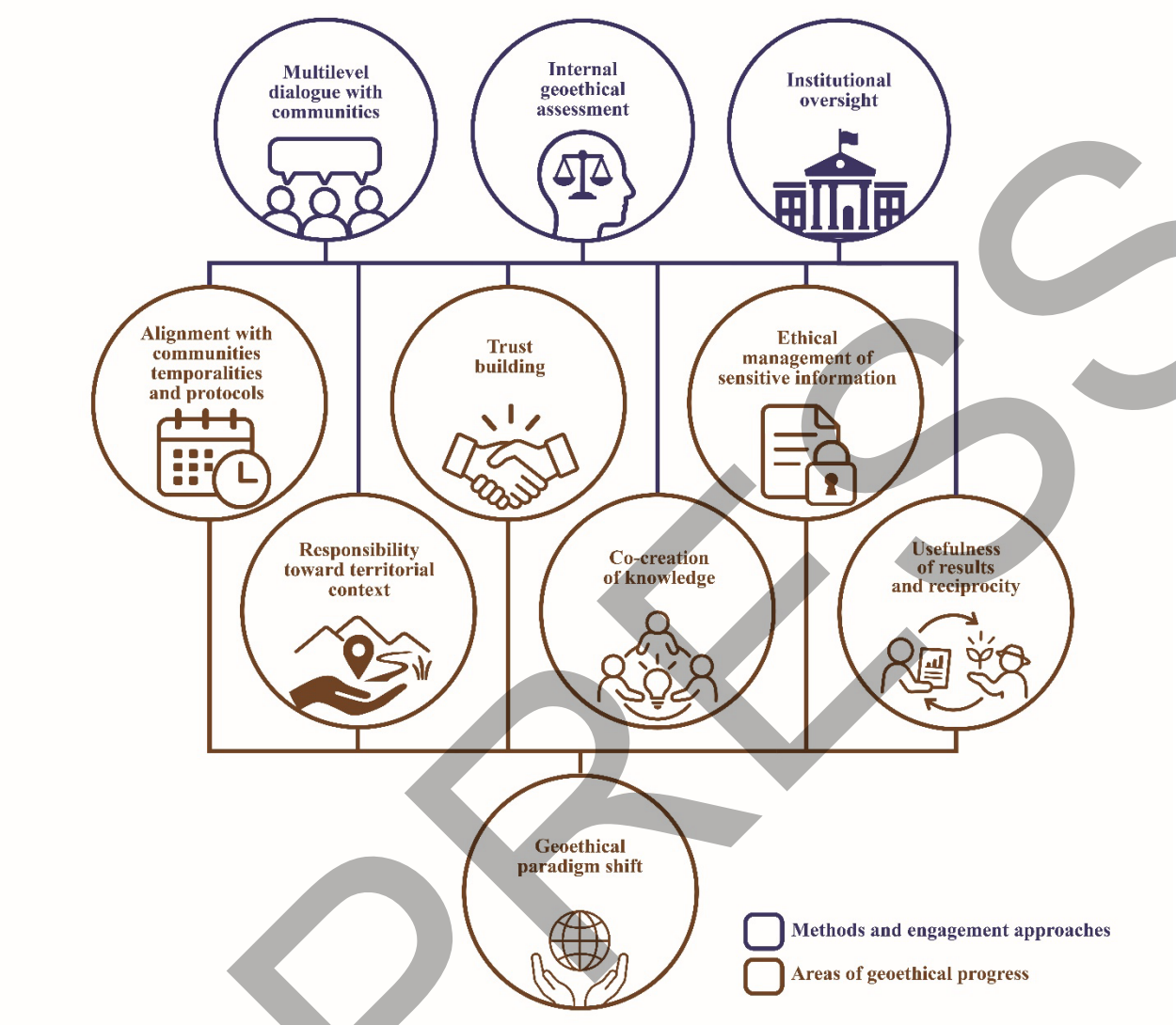

Fig. 2. The relationship between the methods and engagement approaches and the areas in which progress has been made toward a geoethical paradigm shift.

5. Final remarks

The SALARES Project has conducted multidisciplinary research on lithium dynamics in the SDA and surrounding high-Andean salars since mid-2024, within a territory shaped by indigenous governance, state institutions, environmental pressures, and the rapid expansion of lithium

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extraction. We aimed to reframe it as an “ethical space” where diverse worldviews, a technical-extractive focus and an ancestral-relational focus, must engage. This concrete case study has shown that scientific research in socio-environmentally sensitive territories cannot be approached solely as a technical exercise, but must also incorporate intercultural dialogue, flexibility, and geoethical reflection.

This contribution is a concrete example of how research can move from a model of “extraction and mitigation” to a research model that sees Atacameño communities as active agents. Avoiding taking data and knowledge from indigenous territories, in our case SDA, without returning direct benefits or acknowledging local expertise, is aligned with the guidelines for intercultural research from the UdeC in place since 2022 and supported the 2024 Code of Geoethics of the SGCh, moving beyond conducting geoscientific research correctly and responsibly toward greater awareness of its interactions with the Earth system and its implications for local communities. Although geoscientists cannot control how their findings may be used to justify further extraction, a legitimate concern of the communities, they can contribute critically interpreting and communicating scientific evidence and seeking to anticipate and minimize its environmental and social impacts.

The team agreements and their practical implementation reflect the SALARES team's openness to respecting established protocols and incorporating Atacameño communities into the research process, though this remains constrained by the lack of adequate institutional and state mechanisms for implementation. Involving communities during the project formulation stage, before approval, would build trust and strengthen the potential for effective collaboration. However, achieving this requires adjustments at the state level in the allocation of funding and the design of funding calls in order to enable, and potentially finance, these preliminary stages that ensure the viability of

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projects at the time of implementation and enrich them with more diverse and territorially grounded perspectives. Likewise, it seems necessary to broaden funding provisions to cover travel and subsistence costs for individuals external to the project who contribute on either an occasional or ongoing basis.

One of the main concerns among local inhabitants regarding natural science research projects is the potential production of sensitive information that could be used in ways contrary to their environmental, economic, or cultural objectives. It would be important to establish standardized guidelines to facilitate and enhance the transparency of data-use agreements; that is, to implement data governance mechanisms that enable the filtering or anonymization of sensitive data prior to publication, providing a baseline from which a more in-depth dialogue between researchers and the community can be developed.

This experience also highlights the limited institutional development in Chile for intercultural and geoethical research practices in the Earth sciences (Collao Quevedo, 2026). Existing guidelines remain insufficient for addressing challenges related to territorial governance, sensitive environmental information, and collaborative research in extractive contexts. International experiences, such as Canadian frameworks based on indigenous self-determination and data sovereignty, may provide useful references for future institutional development.

Although this research was conceived to contribute scientific knowledge toward a more sustainable understanding of lithium-bearing salar ecosystems, its influence on public debate and decision-making remains constrained by the speed of current political and productive transformations linked to lithium extraction in Chile. At the same time, it represents an effort to incorporate socio-environmental, intercultural, and geoethical dimensions from the early stages of

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implementation, which remains relatively uncommon in large-scale natural science initiatives associated with strategic mineral resources. Despite its limitations, this experience may inform future research practices in socio-environmentally complex and extractive contexts, as it illustrates a broader shift in geoethical responsibility toward considering how the knowledge produced interacts with the Earth system and affects the communities connected to it.

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Suplementary Material

Questionnaire implemented between December 2025 and January 2026 among the project's undergraduate and graduate students regarding the possibilities, challenges, and responsibilities of academia in adopting an intercultural perspective, based on their experiences during their participation in this research. The sample comprises seven undergraduate students (one law student and six geology students), one master's student (public law), and three doctoral students (in earth sciences).

1. Does the SALARES project have a duty to understand the social context of the Atacama region and, specifically, the area around the salars under study, and to adapt to the needs and concerns of the local Atacameño communities?

2. How can academic planning be reconciled with the timelines, rhythms of life, forms of organization, and protocols of the Atacameño communities inhabiting the territory studied by the SALARES project?

3. How could the SALARES project ensure that it does not undermine ancestral or local knowledge related to the territory?

4. How does the role of the researcher change within the SALARES project if local Atacameño communities are recognized as co-creators of knowledge about the territory?

5. What concrete strategies can be implemented to build trust with communities that have historically been marginalized from scientific research?

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6. In your opinion and experience, what mechanisms could be used within the framework of the SALARES project to ensure that research results are useful and accessible to those who participated in the study?

7. What should occur if research conducted under the SALARES project generates strategic information that could be considered sensitive or potentially harmful to people in the territory?

8. How can the most meaningful forms of reciprocity for Atacameño communities be identified within the framework of the SALARES project?

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