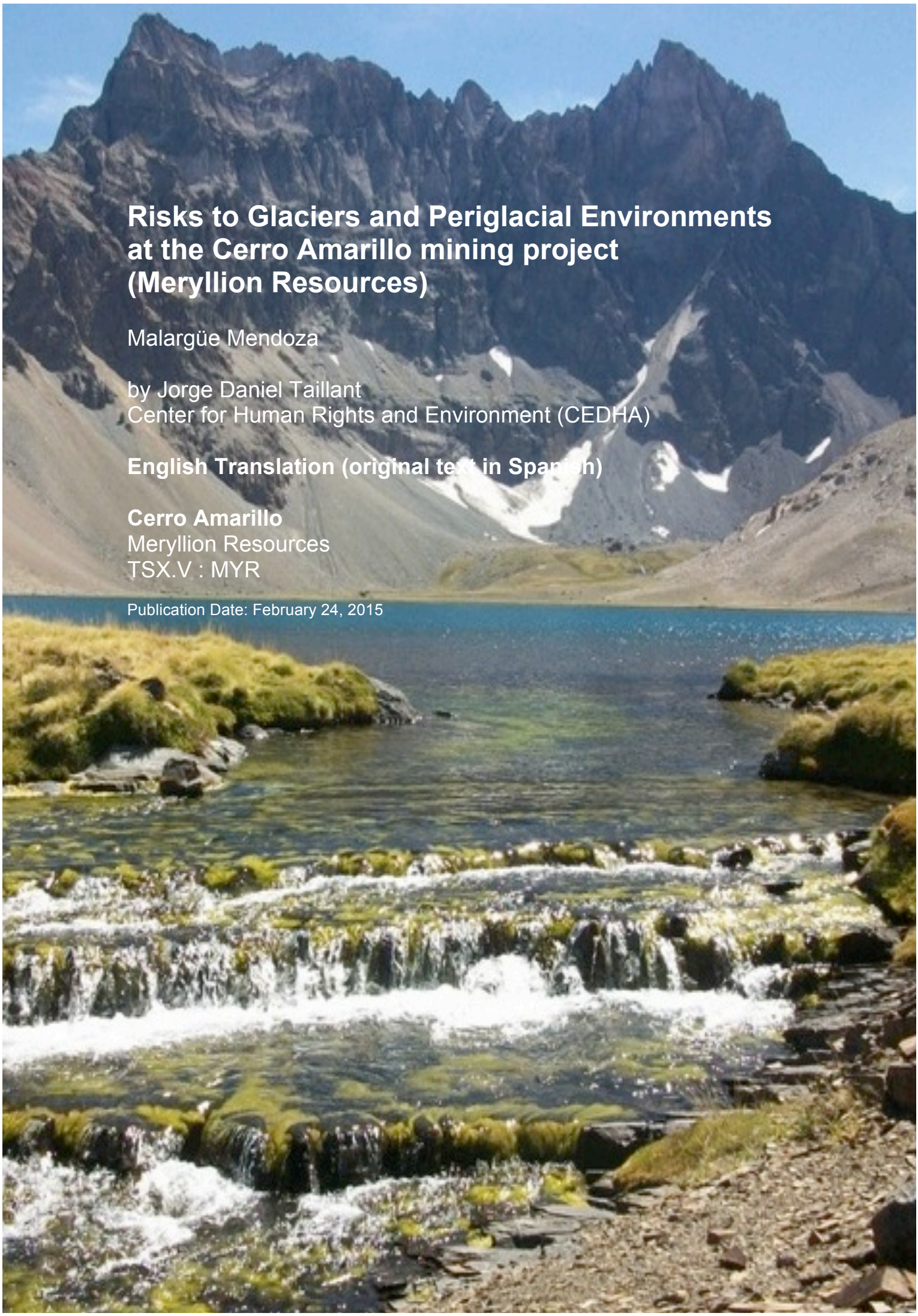

Risks to Glaciers and Periglacial Environments at the Cerro Amarillo mining project (Meryllion Resources)

Malargüe Mendoza

by Jorge Daniel Taillant
Center for Human Rights and Environment (CEDHA)

English Translation (original text in Spanish)

Cerro Amarillo
Meryllion Resources
TSX.V : MYR

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Cover photo: Periglacial environments in the Central Andes feed water basins during dry periods.
Photo location: Laguna del Cajón Grande (in the heart of the Cerro Amarillo mining concession), Malargüe County, Mendoza Argentina
Source: Daniel Warenica

Center for Human Rights and Environment (CEDHA)
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Author: Jorge Daniel Taillant

jdtaillant@gmail.com

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We'd especially like to thank Dario Trombotto Liaudat, a geocryologist of the IANIGLA and member of the CONICET scientific association, for taking time to answer many technical questions on the periglacial environment of the Central Andes. Darío answered numerous questions we posed him about the glacier resources in this report. We also thank Stephen Gruber, of the University of Zurich who has answered questions about, and explained the uses of, his fantastic permafrost remote modeling tool.

We also thank Daniel Warenica who collaborated with CEDHA on a site visit to the Cerro Amarillo area, carrying out a photographic documentation of some of the key hydrological resources at the Cerro Amarillo mining concession. We also thank Mercedes Lu, Heidi Weiskel and Mark Chernaik of ELAW who helped with the identification of satellite imagery useful for this report.

We must also thank those contributors who have played a fundamental role in financially underpinning our work, including UUSC (Patricia Jones) and Patagonia (Raul and Cristobal Costa). We also thank the CEDHA team that collaborated in various parts of this. And finally, Romina Picolotti, who has inspired this and many other environmental causes.

- Jorge Daniel Taillant

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Recommendations to the Reader:

This report is especially conceived so that the reader can use simple technology to see glaciers, rock glaciers and periglacial environments, right on their *smart* devices. Go ahead and open up your maps program on your phone and set the program to satellite mode.

Type the following string in the search box (comma and all): **35 19 30 S, 70 13 59 W**

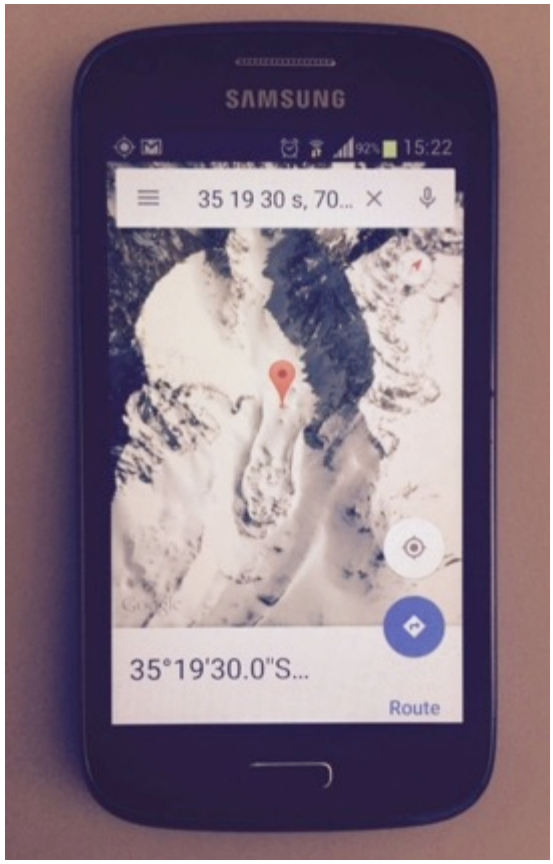
A white area appears after a few moments … you're in the Central Andes … right in the heart of the Cerro Amarillo mining project. Zoom out as needed to gain perspective of the image. What you're looking at is a colossal rock glacier containing millions of gallons of water, stored in ice form ready to be used when the environment needs it most. It looks like a tongue flowing down the mountain towards the bottom right corner of the screen.

This report is about this and other glaciers in the Cerro Amarillo mining concession.

We can get even more interesting without getting too complicated … download the following zipped file.

http://wp.cedha.net/wp-content/uploads/2015/02/Cerro-Amarillo-Project-Polygons.kmz_.zip

Save it, and then open it up in Google *earth* from the file menu in the Google Earth Program. You've now got a glacier inventory of 30 glacier bodies, the mining concession, and other natural resource references, right in your Google *earth* program. You can see these glaciers (or hide them) by simply checking and unchecking the boxes that appear on the left pane in Google *earth*.



You can see Cerro Amarillo's Glaciers right on your phone!

Preface
by Romina Picolotti
Former Environment Secretary of Argentina

This report appears at a watershed moment in the evolution of the implementation of Argentina's National Glacier Protection Law, the first law in the world focused exclusively on the protection of the planet's cryogenic resources.

It is an opportune moment to reflect on the fact that only 2% of the world's water is freshwater, apt for human consumption. Of that water, ¾ of it is in glaciers, and most of it in the polar ice caps. The rest is stored in mountain glaciers that in contrast to polar glaciers are critical water suppliers and water basin regulators for human populations and for agricultural activity during warmer and *drier* months. If it weren't for mountain glaciers and for the periglacial environment, many of the Planet's rivers would be seasonal rivers, drying up quickly once the winter snowfall melts away in the Springtime. Mountain glaciers provide water year round to rivers and basins that feed humanity, agriculture and industrial activity.

It's even more surprising to think that before the adoption of Argentina's National Glacier Protection Law in the year 2008, approved unanimously by the Argentine Congress, no country in the world had a law to protect glaciers, a critical natural resource on route to extinction due to climate change. The reason for this legislative oversight is undoubtedly the lack of social knowledge about glaciers, the fact that very few people actually live in contact with glaciers, and the fact that it is very difficult to reach the very inhospitable environments where glaciers are located and where they thrive. It's very difficult to protect that which we do not know. Before the Argentine Glacier Protection Law, few Argentines knew there were glaciers in provinces like Jujuy, La Rioja, Salta, San Juan, and even in Tucumán—all known to have very dry climates. These glaciers play a fundamental role in these provinces' local water systems.

However, that year, Argentine legislative representatives worked in tandem and with the Environment Secretariat, responding to the call on lawmakers to protect this vulnerable resource. Not one of these congressional representatives doubted the importance of this resource and none of these representatives raised any points of concern over the proposed glacier protection bill. The world's first glacier protection law was approved unanimously, without comments, and without any modification to the proposed text. And yet, just a few days later, the President of Argentina vetoed the law. She was pressured by large mining interests, specifically by the owners and interested commercial stakeholders of a very large binational mining project called Pascua Lama owned by the world's largest gold miner, Barrick Gold. The President of Argentina vetoed the glacier law on the grounds that prohibiting mining in glacier and periglacial areas was "excessive". She also argued that it wasn't necessary to carry out special environmental impact studies where mining was potentially impacting glaciers. She argued that provinces were in the best position, and were the ideal actors to monitor and control mining operations that could harm glaciers and periglacial environments.

I resigned from my position as National Environment Secretary at that time because I felt that the decision of the President was not a good one. I had worked personally from the Environment Secretariat, and hand in hand with congressional representatives, to achieve the legal protection of glaciers that were being dynamited by mining companies. Glaciers were defenseless before an executive power and before provincial powers that were unable *or unwilling* to control mining companies. The State was absent in the face of risks and impacts to glaciers and periglacial areas. The dominant paradigm was to extract and to pillage resources at any social and environmental cost. We have the example of La Alumbrera in Catamarca Province to show this tendency. I believe that before this absolute state of defenselessness, the State must intervene, especially when what is at stake are strategic hydrological reserves and the well being of communities in the region. I have been witness, as a government official, of the unscrupulous behavior of mining companies, as they ignore their environmental and social responsibilities.

Unfortunately, time has only confirmed what we could see was about to happen at that time. Mining has continued uncontrolled onto glaciated and periglacial environments. Pascua Lama

(Barrick Gold), El Pachón (Glencore Xstrata), Los Azules (McEwen Mining), Del Carmen (Barrick Gold/Malbex), Filo del Sol (NGEx Resources), Famatina (Osisko) and many other mining investments are located in glacier and periglacial terrain, and are operating practically without environmental oversight.

The provincial authorities, such as the government of San Juan, authorize companies such as Barrick Gold to move forward with projects like Pascua Lama, when in neighboring Chile, the same project, on the same land, is stalled by the judicial sector precisely for the impacts to glaciers and periglacial environments. Meanwhile, national authorities such as the National Environment Secretariat and the Mining Secretariat fail to comply with the glacier protection law by failing to provide the IANIGLA with information about where mining is taking place, so that the priority inventories and studies mandated by law can shed light on mining risks and impacts to glaciers and periglacial environments.

It has been four years since the promulgation of Argentina's National Glacier and Periglacial Protection Law and we have yet to see a single priority inventory nor a glacier impact study as mandated by Article 15 of the law.

This report by CEDHA is yet another report in a series of reports we have published specifically with the intent to show society the risks and impacts suffered by the high glacier and periglacial environments in the Central Andes and other ranges like the Aconquija Range in Catamarca and Tucuman provinces. The report provides unquestionable evidence that there is an overlap of mining activity with glaciated and periglacial environments. This is yet another call for public officials to take warning, and respond to the urgency presented here and to defend the interests and well-being of communities that depend on glaciers and periglacial areas for their subsistence. This is an inescapable obligation for public officials. Inaction has a permanent cost: environmental harm to these sensitive natural resources is irreversible.

The Mendoza Legislature opportunely stalled the advancement of Meryllion Resource's Cerro Amarillo mining project until the appropriate glacier inventory now being carried out by the IANIGLA is completed. But we must also ensure that the necessary risks and impact studies are also carried out. We need more in-depth studies on the risks and impacts that could occur if Cerro Amarillo is to move forward as planned.

The present report is exclusively focused on this project and identifies glaciers and periglacial environment in the project's concession and zone of influence. We hope that this report will contribute to the effective implementation of Argentina's Glacier Protection Law and to the necessary strengthening of Argentina's State of Law, so necessary now with the present dominance of short-sighted commercial interests that are in frank contradiction with the needs of our vulnerable home.

Executive Summary

The following report aims to bring attention and raise awareness of the risks and impacts that mining activity at the Cerro Amarillo mining project (by *Meryllian Resources*) have had or could have (if the exploration project moves forward) to glacier and periglacial environments of the delicate hydrological ecosystems of the Central Andes.

While it is true that sometimes (although not always) we need to conduct site visits to confirm or discard observations made through the analysis of satellite images, the presence of glaciers and of periglacial environments, and sometimes also of other geoforms of the periglacial environment, are easily identifiable through the analysis of satellite images. The confirmed presence of glaciers and rock glaciers at nearby areas (such as Cordón del Plata an Las Leñas) at similar altitudes is grounds upon which to presume that we could also find glaciers, rock glaciers and periglacial areas at Cerro Amarillo.

According to CEDHA's findings at Cerro Amarillo conclude:

- According to a global permafrost mapping tool developed at the University of Zurich, there is ample possibility of finding frozen grounds in the project's concession area;
- There is the probability or at least the possibility of finding ice-saturated frozen grounds in areas where there may not be rock glaciers visible;
- There are at least three areas in the concession with high probability of finding frozen grounds;
- The majority of the areas that *Meryllion Resources* has targeted for future drilling are in areas where there is at least the uncertainty over the presence of frozen grounds;
- *We know* with absolute certainty that there are ice-saturated frozen grounds in the concession where we have positively identified active rock glaciers;

In one small rock glacier we have identified in the mining concession, a conservative estimate suggests that the glacier contains some 2,000,000,000 liters of water (528 million gallons of water), which if distributed amongst the Argentine population (40,000,000 people), every Argentine would have drinking water for nearly a month.

If we map out the waterways and their relationship to the principal rivers of the region, we see that all of the higher areas where we are likely to find ice-saturated frozen grounds (according to the University of Zurich model), are the birth sites of the various river systems in the concession. This is not a coincidence. The waterways in the concession area all come from the periglacial environment!

Several lagoons are visible in the heart of the mining concession. These form at the base of mountain ravines. As these lagoons continue to outflow into local streams after the seasonal snow has melted, this is undoubtedly due to the permanent and sustained contribution of melt water from the melting of the periglacial environment above.

CEDHA's glacier inventory (see image above) registers 30 glacial bodies (amongst these, 13 uncovered glaciers representing 1.15 km^2 (.44 $miles^2$) and 17 rock glaciers representing 2.58km^2 (1 $mile^2$), for a total area of 3.73km^2 of ice (1.44 $miles^2$) in the Cerro Amarillo mining concession. These glaciers are located at between 2,740 – and 3,690 meters (9000 – 12,100 ft). Argentina's national glacier institute (the IANIGLA) is still working on an official glacier and periglacial environment inventory, including uncovered glaciers and of some of the geoforms of the periglacial environment, such as rock glaciers. However, the IANIGLA will ignore other very relevant ice-saturated cryogenic resources, such as ice-saturated creeping grounds, which are also very significant hydrological resources and which are protected by law. Further, the official inventory will only register glaciers with an aerial surface area of more than 0.01km^2 or 100 x 100 meters (328ft x 328ft) despite the fact that these ice patches can collectively be even more significant in terms of water contribution than larger glaciers, and also despite the fact that these ice bodies (prevalent in the Cerro Amarillo concession), are still very much protected by the Argentine National Glacier Law.

According to the information CEDHA has obtained regarding recent and proposed activity for future mining activity at Cerro Amarillo, combined with the satellite images we have analyzed and which are presented in this report, we can say that effectively there are coincidences between past mining activity, and with present or planned future mining activity with areas that have glaciers, rock glaciers or other periglacial features.

Mining activity can impact glaciers, rock glaciers and periglacial environments due to the introduction of roads, ground removed by excavation, drilling, blasting, traffic and other industrial contamination from mining activity. Further, the various stages of mining work (prospecting, exploration, preparation, extraction, closure) each have diverse and different impacts. While according to the reports by the company, there has only been light exploration at Cerro Amarillo, carried out by horseback, on foot, and by helicopter, CEDHA is concerned over the risks that would be implied if new stages of exploration are to move forward, such as drilling, moving of soil, introduction of roads, prior to the necessary inventories and glacier and periglacial impact studies.

Given that the company has already announced its intention to drill and the specific drill sites where it wants to drill, and that we have already identified the location of glaciers, rock glaciers and periglacial environments, there is enough information present to warrant an in-depth study of eventual risks and impacts of these activities to these resources. Of special concern would be: any drilling on ice-saturated frozen grounds; any movement of soil on ice-saturated frozen grounds; any introduction of roads on ice-saturated periglacial environment; any blasts upwind of uncovered glaciers; any introduction of roads upwind of uncovered glaciers;

It is CEDHA's recommendation that no further permits be authorized for activities at Cerro Amarillo until the appropriate inventories and impact studies are completed and that these studies assure that glaciers, rock glaciers, and other hydrological resources of the periglacial environments (such as creeping grounds, etc.) are not at risk.

The Argentine National Glacier Protection Law is very clear over the importance of cryogenic resources, and establishes the categorical prohibition of activities that might damage this resource. What we need to gauge, hence, is if the activity proposed by the Cerro Amarillo mining project will negatively impact glaciers, rock glaciers or periglacial areas. If it does, it is illegal. If it doesn't then it could legally move forward (at least as concerns glacier protection).

CEDHA calls on public officials, provincial and national authorities specialized in environmental and mining issues, particularly the IANIGLA, the Environment Secretariat and the Mining Secretariat, to ensure that the proper studies are carried out to shed light on the risks to glaciers, rock glaciers and periglacial environments at Cerro Amarillo.

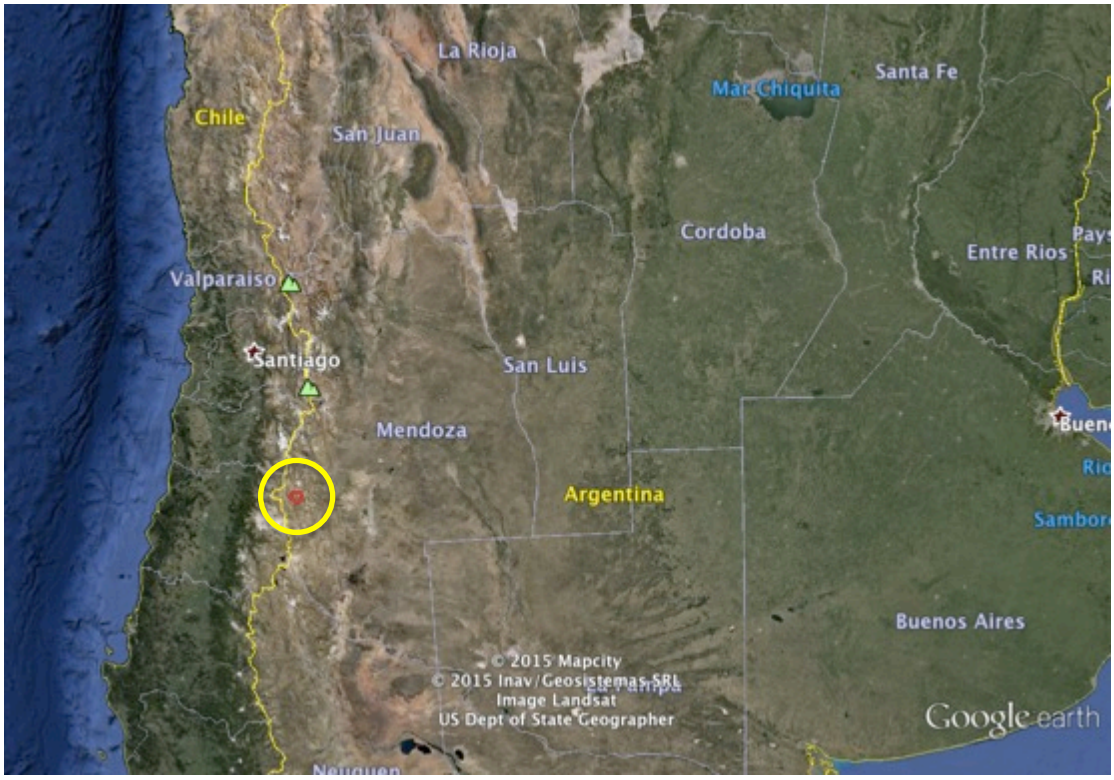
This report by the Center for Human Rights and Environment (CEDHA), offers very clear and certifiable information, showing that there are cryogenic resources (glacier resources) inside the Cerro Amarillo mining concession. CEDHA shows without a doubt that there are glaciers, rock glaciers and periglacial environments in the Cerro Amarillo mining concession. All of these resources are protected by law. CEDHA cannot see, nor does it know of any special environmental impact study to assess risks to these glacier and periglacial resources by *Meryillion Resources* or by any another company or agency. It is time for the State authorities to take the necessary steps to ensure the protection of this very vulnerable and strategic resource.

Background

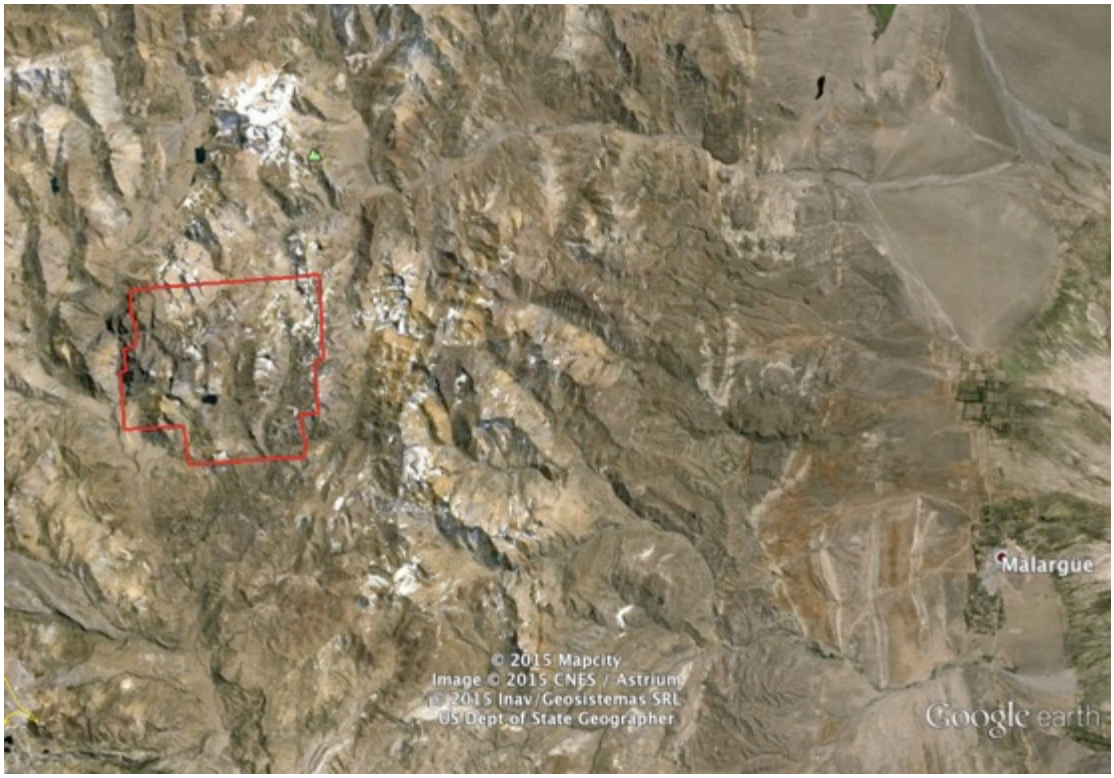
The following report aims to bring attention and raise awareness of the risks and impacts that mining activity at the Cerro Amarillo mining project (by Meryllian Resources) have had or could have (if the exploration project moves forward) to glacier and periglacial environments of the delicate hydrological ecosystems of the Central Andes.

The author is concerned with this potential impact because the project concession is known to be in, or near, glacier and periglacial areas. Argentina's laws in force at present prohibit activities that can harm glaciers or periglacial environments, and expressly prohibits mining in glacier and periglacial areas. Public officials in charge of controlling mining operations and ensuring compliance with Argentina's environmental laws, should be warned and refrain from granting permits for any mining activity in the Cerro Amarillo concession until the official glacier inventories and proper impact studies have been completed.

Public information available online indicate that Cerro Amarillo, located in the county of Malargue Mendoza Argentina, is a gold and copper mining project currently in an initial exploratory phase and comprises terrain of the Central Andes, including areas of the following ranges: *Apero, Vaca de Cobre, Cerro Choro, Cajón Grande* and *La Blanca*. Below are three images that help situate the project for the reader. The mining concession is the red polygon.



Cerro Amarillo Project Location (Meryllion Resources)



Detail of the concession area – Cerro Amarillo

Detail of the project area; Source *Meryllion Resources*

According to Meryllion Resources' website (the company that holds exploratory rights to the mining concession and who has already conducted exploratory activity at the concession), the Cerro Amarillo mining project is located in the Central Andes at an average altitude of 3,000 meters (9,842 ft) above sea level, with an altitudinal variance between 2,000 and 3,800 meters (6,561 – 12,467 ft). [see: http://meryllionresources.com/s/cerro-amarillo.asp]

The company notes that there are substantial mineral deposits in the concession, which make Cerro Amarillo an attractive mining investment. Also according to Meryllion Resources:

> "Much of the project area receives snow from May to November each year resulting in a practical field season of some five months from early December to late April." [1]

Meryllion Resources also suggests that there are ample hydrological resources at the concession. While the presence of snow during the winter months is not necessarily an indicator that one might find glaciers or periglacial areas present in the area, the continued presence of that snow beyond the winter months—*and the short window of access to the site due to the cold weather*—does. This is at least a preliminary indicator that there may be glaciers and periglacial areas at or near the site. But more importantly the region is already known to glaciologists for housing many glaciers and periglacial environments. Periglacial environments, in contrast to more commonly recognized white uncovered glaciers, are frozen grounds saturated in ice, that work, much like normal glaciers, as water reserves and as water basin regulators, providing slow release critical melt water after the seasonal snow has melted in the spring. This is why the Argentine Glacier Law protects these sensitive ecosystems.

In a recent report published in 2012, by the Argentine Snow, Glacier and Natural Sciences Institute (IANIGLA), the area just north of Cerro Amarillo called *Cordón del Plata*, is designated as a glacier and rock glacier area, at elevations between 3,200 and 4,100 meters (10,500 – 13,500ft).[2]

We should clarify that as one approaches the polar regions, glaciers are found at lower and lower altitudes, due to which we can presume that without even analyzing satellite images of the terrain at Cerro Amarillo, as we go further south from Cordón del Plata (Cerro Amarillo is further South), there is probability of finding glaciers and/or periglacial environments at the very least at similar altitudes or even at lower altitudes than Cordón del Plata. If we consider the nearby ski resort of Las Leñas, for example, we can find active rock glaciers as of 2,900m (9,500ft).[3]

Considering that Cerro Amarillo is between 2,000 and 3,800m (6,500 and 12,500ft), and that it is further South than Cordón del Plata, and also further South from Las Leñas ski resort, we can easily conclude that there is a likelihood of finding periglacial environments at Cerro Amarillo at its average elevation of 3,000 meters (9,840ft). Evidently, each terrain may have its own micro-climate and these may vary quite a bit from site to site. And while this supposition is not sufficient to assuredly conclude that there is presence of periglacial areas at Cerro Amarillo, we can certainly sustain that there is enough probability to warrant a precautionary approach to the issue, and to mandate all types of industrial activities taking place in the area to carry out full glacier inventories and glacier and periglacial impact assessments in order to protect glaciers and periglacial environments.

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[1] see: http://meryllionresources.com/s/cerro-amarillo.asp
[2] see: http://www.glaciaresargentinos.gob.ar/informes/MZ_ING_Plata_31_10_13.pdf; p. 24
[3] see for example:
a) 35°08'19.75" S 70°07'20.79" W
b) 35°09'46.54" S 70°09'30.20" W

Cerro Amarillo is located more than 250 km South of the *Cordón del Plata* mountains (where there are rich periglacial areas), which leads us to presume that is it more than reasonable to presume that there is likely to be periglacial environments at similar altitudes (or even lower) at Cerro Amarillo.

While today, in compliance with the National Glacier Protection Law, law number 26.639,[4] a national glacier and a partial periglacial inventory is underway and being carried out by the IANIGLA, not all periglacial forms will be inventoried. The IANIGLA glacier inventory will not fully register all periglacial resources. Furthermore, none of the relevant agencies, the IANIGLA, the Environment Secretariat, the Mining Secretariat, or the Provincial Authorities, have complied with the National Glacier law, as per Article 15[5] which calls for carrying out within 180 days of the sanctioning of the law (date which expired in April of 2011), priority inventories and specialized studies to analyze the potential risks and impacts of industrial activity such as mining to glacier and periglacial resources. In the case of the Cerro Amarillo mining project, this study should have been carried out by April of 2011. We are already four years into the full implementation of the Glacier Protection Law, and no such study has been demanded or completed, which implies non-compliance of public duties by all of the responsible agencies and actors.

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[4] see: http://wp.cedha.net/wp-content/uploads/2012/10/Argentine-National-Glacier-Act-Traducción-de-CEDHA-no-oficial.pdf
[5] see: http://wp.cedha.net/wp-content/uploads/2011/04/ley-glacieres-definitiva.pdf

Art. 15. – Transitory Disposition
In a maximum period of sixty (60) days beginning with the sanction of this law, the IANIGLA shall present to the national implementing authority a chronogram for carrying out the inventory, which shall commence immediately in such zones where due to the existence of contemplated activities in Article 6, are considered priority. In these zones, the inventory stipulated in Article 3 shall be carried out in a period of no more than 180 days.

With respect to the competent authorities, these shall provide all the necessary information pertinent that the cited institute requires;

The activities described in Article 6, in progress at the moment of the sanctioning of the present law, must, in a period of no more than 180 days from the promulgation of this law, submit to an environmental audit in which potential and actual environmental impacts to glaciers are identified and quantified. In the case of verification of negative impacts to glaciers or the periglacial environment, contemplated in Article 2, the authorities shall order the pertinent measures so that the present law is complied with, and could order the ceasing or relocation of the activity and protective measures, cleaning and restoration as appropriate.

It is because of these failures to comply with the law that the Center for Human Rights and Environment (CEDHA), which has already produced numerous studies examining the impacts of mining activity to glacier and periglacial areas, is publishing *this report*, with the aim of warning of the apparent potential risks and impacts of allowing mining activity to advance at Cerro Amarillo without first conducting the necessary inventories and official impact studies. Additionally, this report aims to bring attention to public officials over these risks, offering a *preliminary glacier and periglacial environment inventory* of the Cerro Amarillo mining project concession. This warning and information is directed and especially targeted to the public officials and legislatures that must decide on the granting of further exploratory or extraction permits to *Meryllion Resources* or to any other company that desires to carry out mining activity in the project concession area. We also advise other public officials, of other national and provincial agencies that have domain over mining activities, that they must comply with their due diligence and with the law to ensure the protection of glacier resources in the region.

Access to Satellite Images

In order to carry out a glacier scoping exercise, as well as detailed studies of glacier and periglacial areas, the most important technical resource needed is good high-resolution satellite imagery of the area studied, from a series of consecutive years, and preferably from days without cloud cover or seasonal snow. In such images, one can easily identify glacier and rock glacier resources (rock glaciers are glaciers with a cover and mix of rock debris). In some cases, we can also identify other elements of the periglacial environment, as for example, frozen creeping grounds, which are also hydrologically important resources.

Generally, satellite companies sell these images to interested clients, although they may also be obtained through publically available internet-based programs such as Google *earth*. Public agencies, for example space agencies, may also provide satellite images to interested parties. In some cases these images can be very expensive, while in others, they may be offered at no cost, particularly when they are for use for the public interest. In Argentina, the CONAE (the national space agency), has access to high resolution satellite images. Through its mandate, the CONAE can sign memorandums of collaboration with public interest groups, including NGOs, and provide satellite images at no cost.

Unfortunately, when CEDHA began our work in 2010 to study satellite imagery to identify mining activity affecting glaciers, the political officials of the CONAE, in complicity with the Environment Secretariat, obstructed CEDHA's access to these images, arguing that it was not necessary for an NGO to carry out a glacier inventory, since the IANIGLA was already preparing a national glacier inventory. This rejection of our request to public access to satellite images, was not only a violation of CEDHA's right to access information, but also shows the national government's intention to withhold information from society about the risks of mining operations. It is a blatant non-compliance with, and violation of, the National Glacier Protection Law.

We recall that this is the same government administration (currently in office at the time of the publication of this report) that vetoed the National Glacier Law when it first appeared in 2008. This veto was leveraged by companies like Barrick Gold and other interests in the mining sector, including pressure from the National Mining Secretariat and by executive officials from mining provinces such as San Juan, Catamarca, La Rioja, and Jujuy. This is *not* the subjective opinion of the author of this report, but rather, it is the actual justification cited by the president's office when she vetoed the unanimously approved Glacier Protection Law.[6]

We also recall that at that same time, then Secretary of Environment, Romina Picolotti, now acting president of CEDHA, resigned from her position as Environment Secretary, because of the President's refusal to provide federal protection to glaciers and their hydrological functions. The present negligent acts of the government with regards to the protection of

[6] see (in Spanish only): http://www.infoleg.gov.ar/infolegInternet/anexos/145000-149999/146980/norma.htm

cryogenic natural resources (ice resources) and its lack of will to implement the national glacier protection law, demonstrated on numerous occasions since its adoption in 2010, and by failing to comply with the dates established for the realization of priority inventories and glacier and periglacial impact studies, is showing lamentable complicity by the national government with the many violations we are seeing to the national glacier law by a number of mining companies in the high Central Andes, including Barrick Gold, Glencore Xstrata, McEwen Mining, NGEx Resources, Stillwater, and others.

Regardless of the national government's refusal to grant CEDHA access to satellite images, we have been able to obtain these images from a variety of other sources, including Google *earth,* other space agencies, and through personal and institutional collaborators with our initiative. With these images, we have been able to conduct our own glacier and periglacial environment inventory.

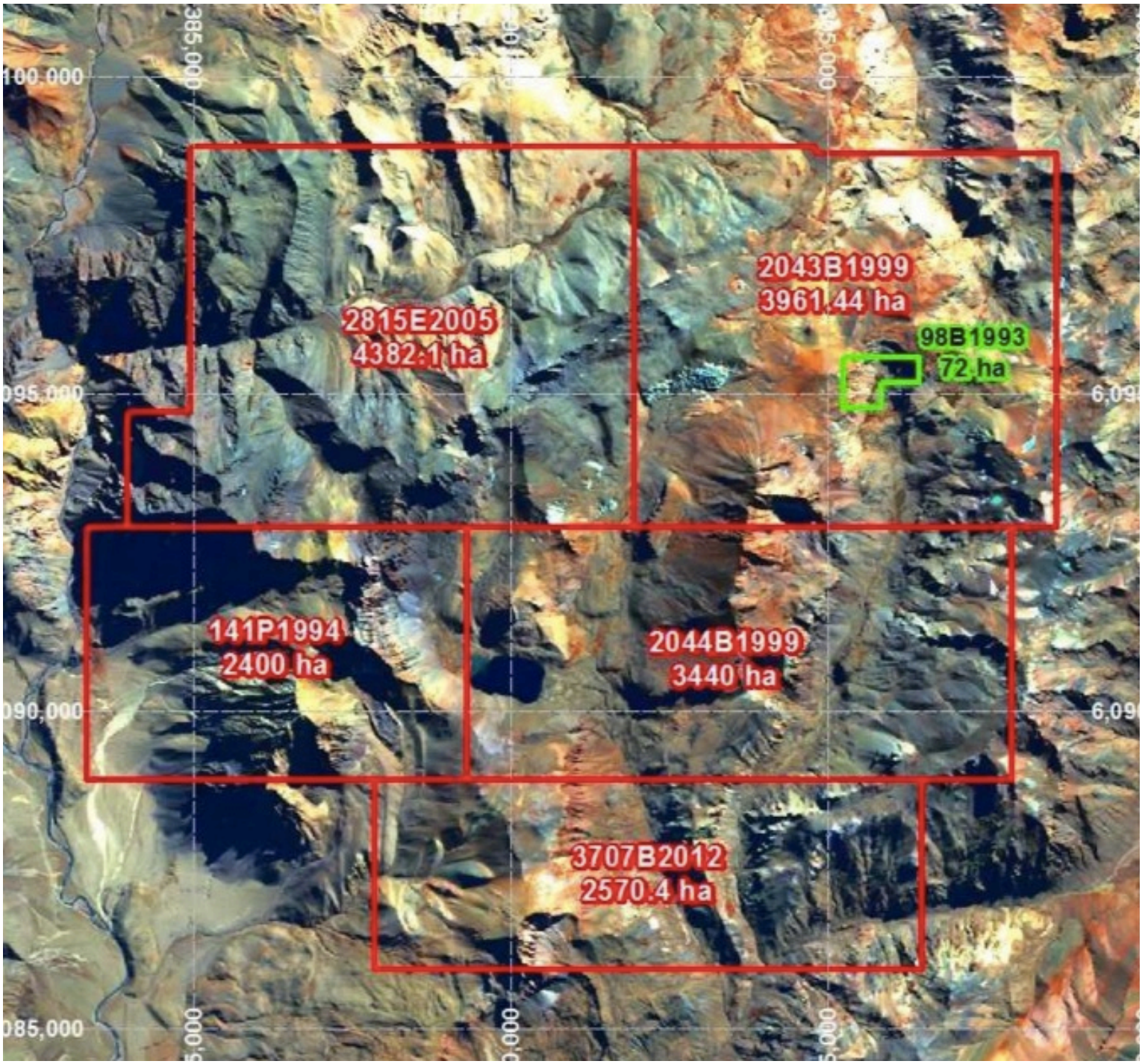
Characteristics of the Cerro Amarillo Mining Project

According to the mining company *Meryllion Resources*, the Cerro Amarillo mining concession is 168km^2 (65 square miles) large and is located at an average elevation of 3,000 meters (9,800ft), with a varying elevation between 2,000 and 3,800 meters (6,500 – 12,500ft).

The concession is about 60km (37 miles) to the North East of the city of Malargue and at only 10km (6 miles) as a crow flies from the ski resort, Las Leñas. We should also mention that the Las Leñas ski resort is also located on periglacial environment, including various active as well as inactive rock glaciers. As such, and considering its current site, Las Leñas ski resort is also mandated by law to carry out a glacier impact study for activities at the ski resort.

The heart of the Cerro Amarillo mining concession is approximately at the following coordinates (visible on your smartphone is satellite mode):

35 18 12 S, 70 11 27 W



Mining History at Cerro Amarillo

The Cerro Amarillo mining property was first discovered by *Minera Aguilar* (St. Joe Minerals) in 1970. *Solitario* conducted studies and additional sampling in 1994-95 at the *Cajón Grande* area. In 1995-96, *Phelps Dodge* carried out additional mapping and in the years 1996-97, BHP Billiton carried out further exploratory work. In 1998, Billiton conducted magnetic mapping at the concession and in 1999, IMA repeated Aguilar's original activities. The property was later explored by *MIM/Xstrata*. In 2006 *Latin American Minerals* carried out additional exploration and in 2008-2009 *Constitution Mining* also undertook mapping. Finally, in 2011-2014 *Meryllion Resources* continued the task of mapping *Cajón Grande* and carried out prospecting activity at *La Blanca* and later at *Vaca de Cobre* and *Cerro Choro, Cerro Apero* and *Cajón Grande*.

Meryllion Resources

Meryllion Resources is a Canadian mining company listed on the Toronto Stock Exchange (TSX Venture Exchange: MYR) operating in Argentina under the subsidiary name Meryllion Minerals Corporation (MMC) and Meryllion Argentina, SA (MAS) and holds mining rights in Argentina over two mining projects, *Cerro Amarillo* and *Providencia* (in Jujuy Province).

In July of 2014, Meryllion Resources published a technical report[7] (which has extensively informed CEDHA's report) and presented the same year, an environmental impact study to the Province of Mendoza (a study which CEDHA could not obtain, despite requesting the report to Meryllion Resources).

While CEDHA offered Meryllion Resources the opportunity to comment on the findings of this report, and on CEDHA's glacier and periglacial inventory, the company has decided not to exercise this opportunity at this time.

Permits, Rights and Activity by Meryllion Resources at Cerro Amarillo

In Meryllion's Techical Report on Cerro Amarillo, the company indicates that it has bought mining rights and has an option to buy the rights for the Cerro Amarillo concession from Jorge Bengochea and Lydia Espizua,[8] and has paid the sum of US$300,000 during the years 2010 through 2014. The company must pay an additional US$400,000 for the 2015-2016 period. If the company later intends to extract minerals from the concession, it must pay an additional US$2.5 million to the owners of the mining rights and will also pay the owners an additional 1% of the earnings of the concession. The mining company also has surface rights granted by the company Las Leñas, SA, which operate the nearby ski resort of the same name.[9]

According to the information obtained on the website of the company, to date, the following activity has been carried out at Cerro Amarillo during the 2011/2012 and 2012/2013 seasons:

- prospecting and sampling over much of the property;
- detailed mapping over Cerro Apero, Vaca de Cobre, Cerro Choro, Cajon Grande, and La Blanca;
- geochemical sampling on grids over Cajon Grande and Vaca de Cobre as well as talus sampling along scree slopes and crests at la Blanca and Cerro Choro;
- induced polarisation surveying over Cajon Grande and Cerro Apero; and,

[7] see: http://meryllionresources.com/i/pdf/reports/CA_43-101.pdf

[8] Lydia Espizua is a geologist and glacier specialist working for the IANIGLA. The glacier staff of the IANIGLA is the team that carries out the glacier inventory, including the inventory of glaciers in the Cerro Amarillo concession. This apparent conflict of interest between IANIGLA's staff carrying out the glacier inventory and the financial loss for one of those staff that would be implied should the IANIGLA determine there are glaciers in the concession which as a consequence might imply the illegality of the project, was brought to the attention of the IANIGLA by CEDHA. In response to our concern, the IANIGLA sustained that Lydia Espizua is not participating in the inventory of glaciers in the Cerro Amarillo concession.

[9] *Technical Report on the Cerro Amarillo Project*. Pp. 4-5 y 4-6

- helicopter-borne magnetic and radiometric surveying over the entire Cerro Amarillo property.

There are no visible roads inside the mining concession, restricting access to the concession site. Meryllion Resources indicates that its work at the concession to take samples has been carried out on horseback and by helicopter, which would coincide with the analyzed satellite images which do not show roads entering the concession.

Given the good results from sampling activity, the company intends to advance to a drilling phase of exploration in which it would perforate some 5,300 linear meters (17,400ft) of grounds at 14 different locations throughout the concession. Below is a map of the projected sites for drilling (this information was published by Meryllion Resources).

According to Mendoza Province's laws, the company must obtain permits to operate and for continued drilling from the Mendoza Legislature. The Mendoza Legislature recently stopped all activity at Cerro Amarillo, refusing to grant Meryllion's permits for further work, until the IANIGLA completes its glacier and periglacial inventory.[10] Meryllion Resources announced in a more recent press release, dated December 1, 2014, that it:

> "After evaluation of recently obtained information regarding the current status of the DIA [its' environmental impact study], the Company has concluded that it is unlikely it will be able to undertake its anticipated 2015 drill program at Cerro Amarillo".[11]

Climate

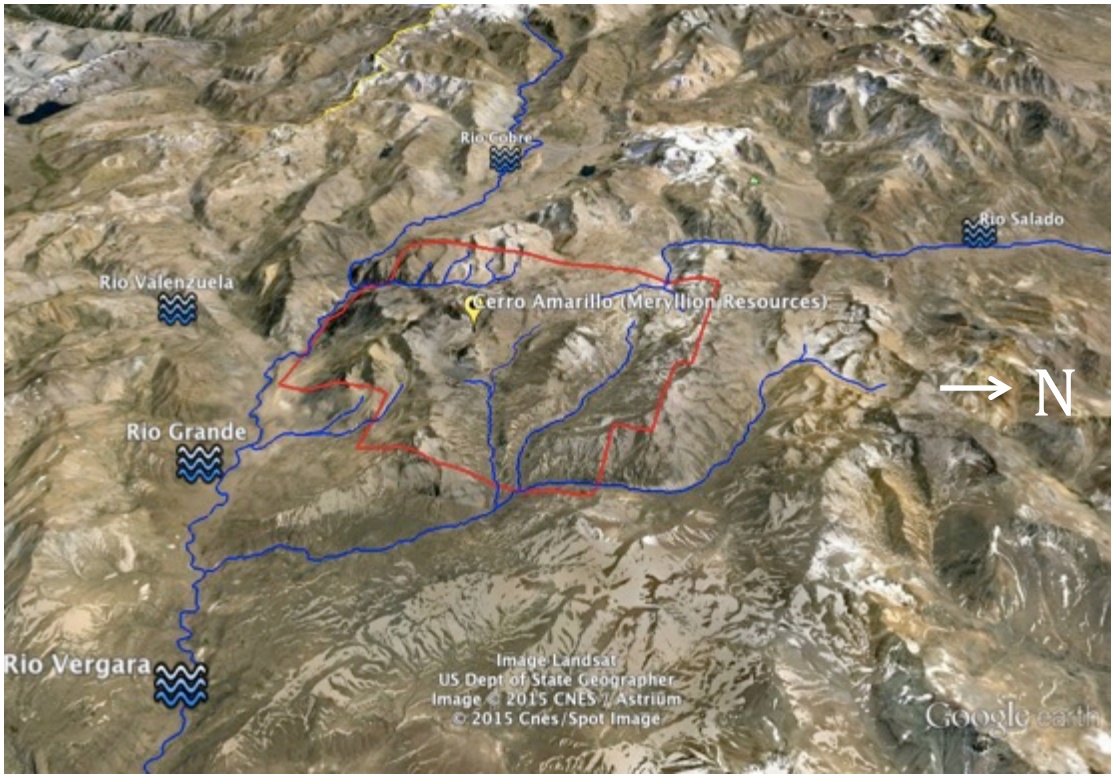
The majority of the surface of the concession receives snow during the months of May through November, which leaves only the months of December through April for mining activity.

Hydrology at Cerro Amarillo

The company indicates that the area of the concession has ample hydrological resources, both inside the concession as well as from the Rio Grande basin, to the West.[12]

The concession is located principally on the Rio Grande Basin, and one portion (the North East) feeds the *Rio Salado* Basin through the El Desecho stream. The concession includes four principal ravines, *El Cajón de los Oscuros* in the North East, the *Cajón Grande*, the *Cajón Chico* and the *Cajón del Infiernillo* to the South. There is a lagoon at the foot of the *Cajón Grande* called *Laguna del Cajón Grande*.

[10] see: http://www.portalminero.com/display/NOT/2014/10/21/Mendoza,+se+frena+el+proyecto+Cerro+Amarillo+y+avanza+Hierro+Indio
[11] see: http://www.marketwired.com/press-release/drilling-permit-update-regarding-meryllions-cerro-amarillo-project-in-argentina-tsx-venture-myr-1972927.htm
[12] see: http://meryllionresources.com/s/cerro-amarillo.asp



The Cerro Amarillo concession (red polygon) and the principal rivers in its vicinity.
Source: CEDHA/Google *earth*

The rivers and streams that feed the environments in the concession, also feed key hydrological basins, principally of the *Río Salado* and the *Río Grande* (which is also an affluent of the *Río Colorado*). The *Río Atuel* also receives water from these rivers and streams. These rivers provide significant volumes of water to communities in the provinces of Mendoza, Neuquén, Río Negro, La Pampa and to part of Buenos Aires province. The *Río Grande* is Mendoza's most plentiful river.

Glacier Environments Visible in Satellite Images

A first point of clarity, important to sustain the work presented in this report, is to explain the value of satellite images to the identification and inventorying of glaciers and periglacial environments. This point is particularly important as a number of individuals, principally in the mining sector, have suggested that the identification of glaciers from satellite imagery is merely "desktop work" and has no validity if it is not accompanied by site visits.[13]

This affirmation by representatives of the mining sector is simply false. We note for example, the opinion of the most notorious Latin American glacier agency, the IANIGLA, which states:

> "The interpretation of satellite images by an experienced operator **is considered still the best method to register high level information about the different types of glaciers.** Although the manual digital registration is a tedious activity, a trained operator who is knowledgeable of the region, can generally produce precise delineations of very trustworthy quality." (IANIGLA. Fundamentos y Cronograma … p. 34; *bold is added*)

While it is true that sometimes (although not always) we need to conduct site visits to confirm or discard observations made through the analysis of satellite images, the presence of glaciers and of periglacial environments, and sometimes also of other geoforms of the periglacial environment, are easily identifiable through the analysis of satellite images.

[13] This is for instance, the critique made by Javier Ochoa, Chief of Operations for El Pachon (Glencore Xstrata), of CEDHA's glacier inventory work for El Pachon. see: http://www.miningpress.com.pe/nota/110863/argentina-glaciares-ms-cruces-entre-xstrata-pachn-y-la-ong-de-picolotti-

In the following image, extracted from the technical report of Cerro Amarillo, published by Meryllion Resources, taken by the Landsat Satellite, probably during the end of the winter season (February or March), we can identify some areas with the probable presence of perennial ice—*which would be glacier ice*.

A simple definition of glacier ice is ice that lasts for at least two year-long cycles which include both summers. That is, if the ice on a mountain surface survives for two consecutive summers, without fully melting, it is considered glacier ice.

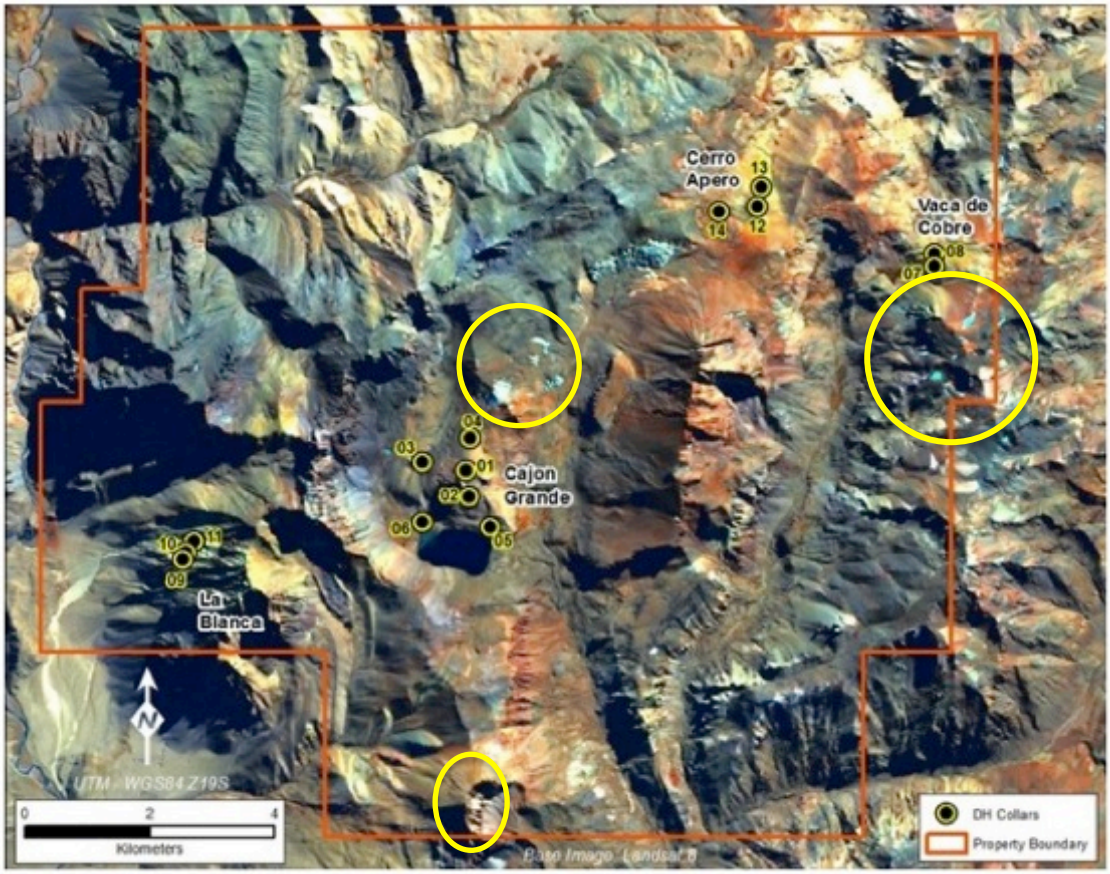
We recall that the Glacier Protection Law of Argentina, with respect to the definition of a glacier, does not establish a size determination for glacier ice. Instead it defines the glacier by the nature of the ice, indifferent to the size of the glacier:

> Art. 2° – Definition.
> As per the present law, we understand glaciers to be all perennial stable or slowly-flowing ice mass, with or without interstitial water, formed by the re-crystalization of snow, located in different ecosystems, whatever its form, dimension and state of conservation. Detritic rock material and internal and superficial water streams are all considered constituent parts of each glacier. (unofficial translation by CEDHA).[14]

We must take into account (and such is the case in the Glacier Protection Law) that a series of cold winters may recharge mountain areas with snow and ice, and accompanying and prolonged and sustained cold temperatures will recharge glaciers, and even create new temporary glaciers, that survive long enough to act as significant hydrological supplements to the water basin systems, especially during later drier and warmer periods. These “small and temporary glaciers” are also protected by the Glacier Protection Law.

If we analyze two or three images in distinct sequential years of a same site, we can say that we see perennial ice if the accumulation of ice year after year, conserves the same form and shape. With the “time” feature in Google *earth*, we can see such cases easily. In the following images, taken from Google *earth,* we indicate sites of interest with yellow ovals. These would be areas where ice survives the heat of summer (perennial ice) and would be considered by definition, glacier ice.

[14] see: http://wp.cedha.net/wp-content/uploads/2012/10/Argentine-National-Glacier-Act-Traducción-de-CEDHA-no-oficial.pdf

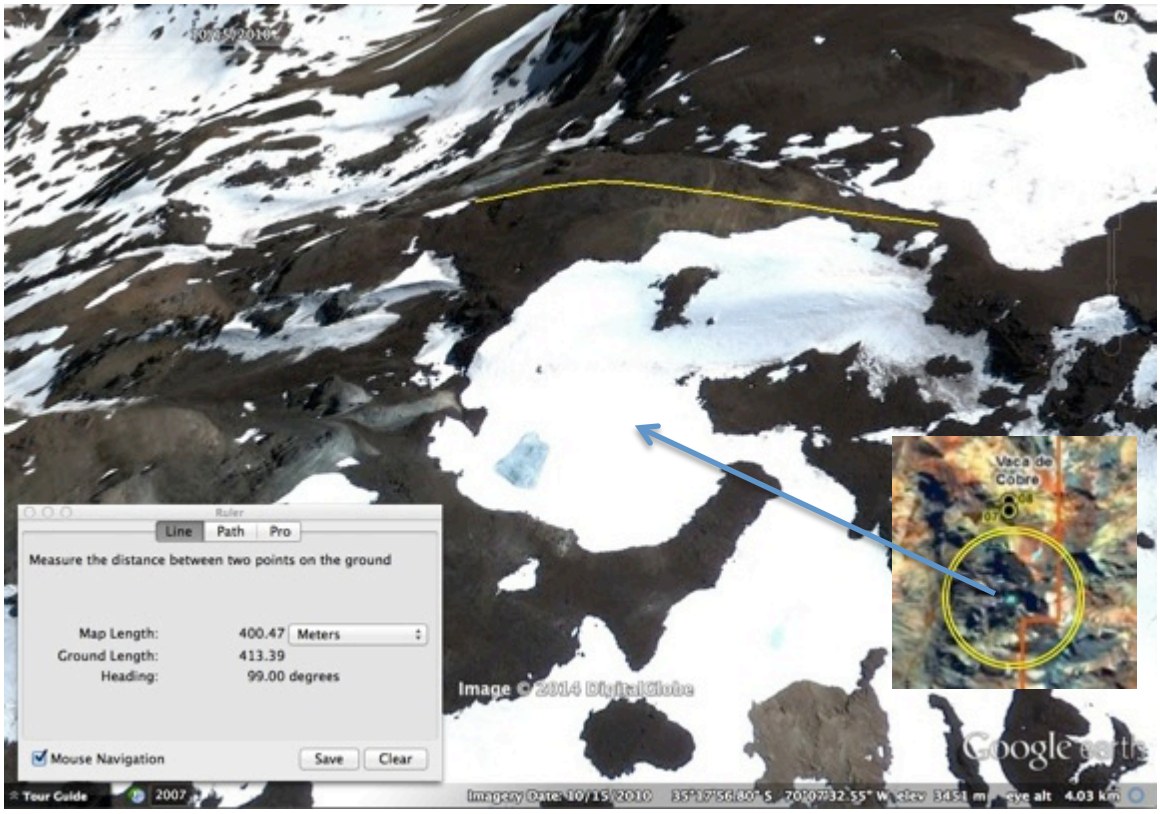


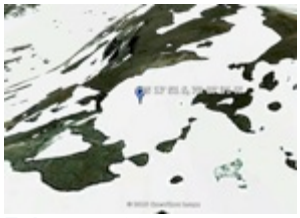
Satellite images published by *Meryllion Resources* show areas of uncovered ice in the Cerro Amarillo concession. Source: http://meryllionresources.com/s/cerro-amarillo.asp

To get a better idea of the size of these bodies of ice, we can get closer to one of them using a program like Google *earth.* In this case we are looking at a small glacier located in the far Eastern portion of the concession (to the South of Cerro Vaca de Cobre), at the following geographical coordinates. You can see it on your smartphone quite clearly!

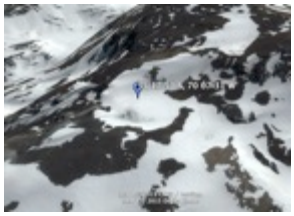
35 17 51 S, 70 07 31 W

In the sequence of images taken from the years 2006, 2010 and 2013, we see that the area of ice maintains its form quite well, indicating the sure presence of perennial ice.




February 2006


March 2010


October 2013

How much water does this relatively small glacier hold?

A quick estimate of the hydrological content of this glacier, supposing an approximate thickness of 3 meters (it is probably 3 to 4 times as thick or more).

400m X 200m = 80,000m^2

80,000m^2 X 3 meters thick = 240,000m^3

1m^3 of ice = approximately 1,000 liters of water[15]

so, this glacier holds some 240,000,000 liters of water (or 63 million gallons)

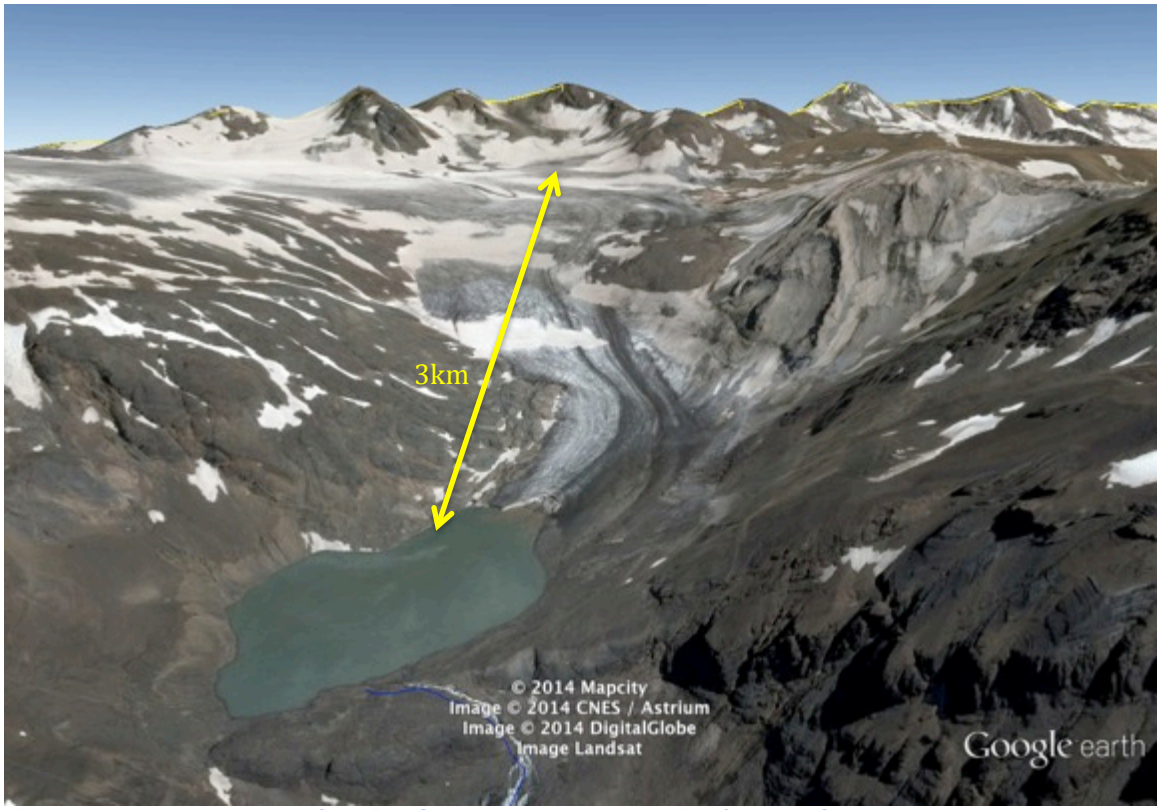
If we consider that per person we consume about 200 liters of water per day (53 gallons), for drinking, hygiene, and other domestic uses, then this small glacier could provide water to the entire population of Malargue county –all the people living near the glacier—(population 29,000), for more than a month, or 41 days. [16]

[15] In truth, a cubic meter of water holds about 920 liters of water. We have calculated the volume at 1,000 to make the math easier, however we have greatly underestimated the probable thickness of the glacier to produce a very conservative estimate of the water content. The likely content is actually several times higher than what we cite!
[16] This calculation is done in the following manner:
240,000,000 liters / 29,000 inhabitants = 8,276 liters per person
4,800 liters / 200 liters per day = 41 days of water.

In the example, we consider a small glacier. But if we pull back from the concession, to the nearby border of Chile, just to the North or to the West, some 25km kilometers away (15.5 miles), we find very large uncovered glaciers (outside the mining concession), which are very extensive and massive. This is the case of the next example at the head of the *Río Grande* River Basin. In the next image we see the birth of the *Río Grande* beneath an enormous glacier that is more than 3km long and wide (about 2 miles long and wide). You can see this colossal glacier on your smartphone at:

34 59 57 S, 70 18 11 W

It's pretty big, so you'll have to zoom out once the image loads, or you'll be right on the glacier and not see its magnificent expanse!



Massive glacier at the head of the Río Grande river basin, 15 miles from the Cerro Amarillo concession.

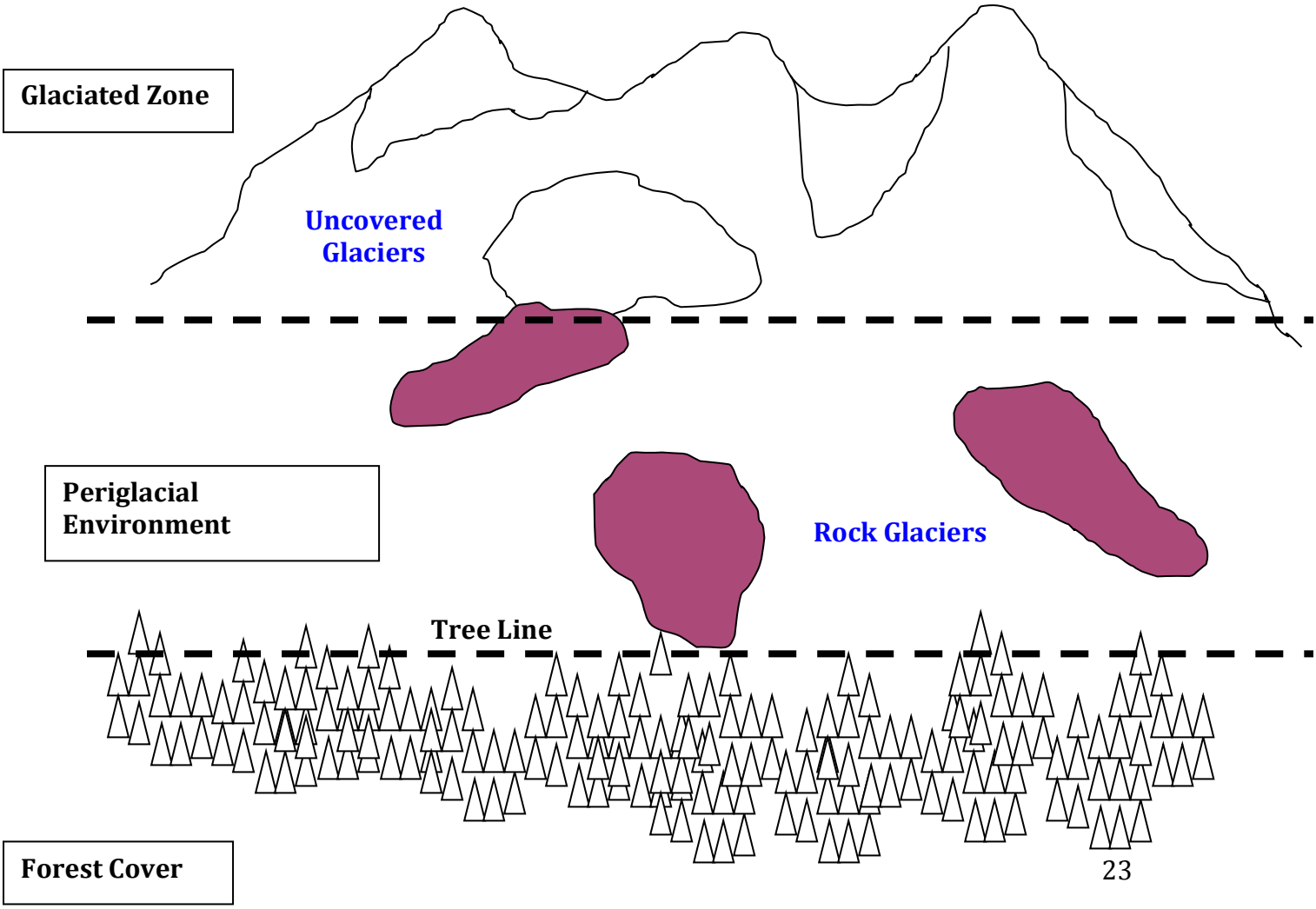
While there are no massive glaciers of this proportion inside the Cerro Amarillo concession, they are nearby, and we should ask what the impacts may be of volatile debris and dust deriving from mining operations and entering the airstream in this vicinity. To determine likely risks and impacts, detailed studies need to be carried out to estimate dust emissions and corresponding potential impacts on nearby glaciers. Dust accumulated on glaciers darkens the surface, changing the glacier's albedo (reflective capacity), and in this way, can cause the glacier to absorb more heat and accelerate its melt.

Simply by analyzing publically available satellite images, and by the information published by Meryllion Resources which clearly shows the presence of ice, we can deduce that without a doubt, there are glaciers present at the Cerro Amarillo mining concession. We will now focus more in detail on these glaciers.

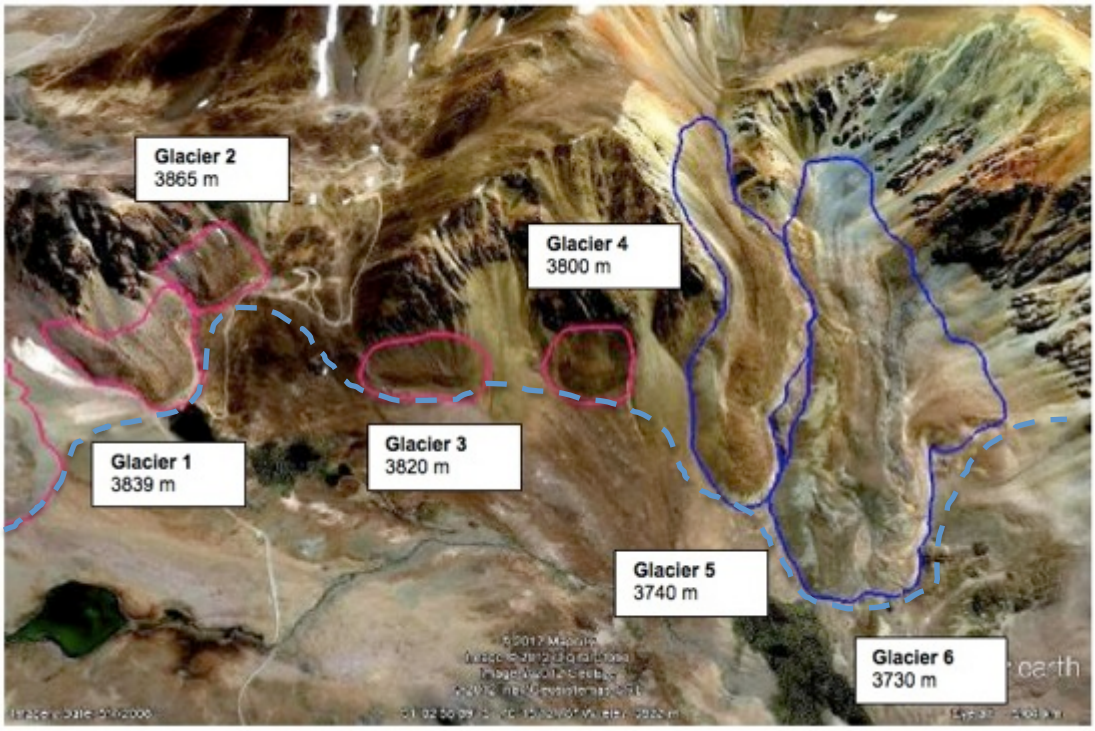
The Periglacial Environment and Frozen Grounds

There are lands in the high Central Andes (an in many other high mountain ranges) where you cannot see perennial ice, but where the mountain remains frozen year round. This area is defined by its geographical and topographical characteristics, and more importantly, by its temperature. It is a land that lies somewhere between the lower limits of visible glaciers and the upper limits of vegetation (or the tree line).

The renown glaciologist and founder of Argentina's glacier institute (the IANIGLA), Arturo Corte, defined this area as a strip of land some 1,600 meters wide (5,250ft), and that in the Central Andes is at approximately 3,200 to 4,800 meters in altitude (10,500 to 15,700 ft). The border of this strip can intermix with the adjacent environments, but essentially, these are the limits of the *periglacial environment*.



One of the traditional ways that have been used to identify the presence of periglacial areas is with the identification of rock glaciers, that is, debris-covered glaciers mixed with rock content, that are visible in the natural environment due to their characteristic forms. This methodology is not treated in depth in this report, but basically it consists of taking the lowest altitudinal point of visible active rock glaciers (*more on active rock glaciers later*), and drawing a line from tip to tip between rock glaciers. The resulting line would be the approximate lower limit of the periglacial environment. In the following image we see rock glaciers (the magenta and blue polygons) with the altitudinal limits indicated at each glacier. Glacier 1: 3,839m (12,600 ft), Glacier 2: 3,865m (12,680ft), Glacier 3: 3,820m (12,530ft), etc. The light blue dotted line that unites the lower tips of these rock glaciers would be the approximate lower limit of the periglacial environment for this area. This would be approximately 3,800m (12,570ft). In this image we don't see white uncovered glaciers, but generally they would be located just above the upper limit of the periglacial environment. In a hypothetical example, where we can see uncovered glaciers beginning at say, 4,500m (14,760ft), we can say that the periglacial environment is between 3,800 and 4,500m.



The lower limit of rock glaciers denotes the lower limit of the periglacial environment.

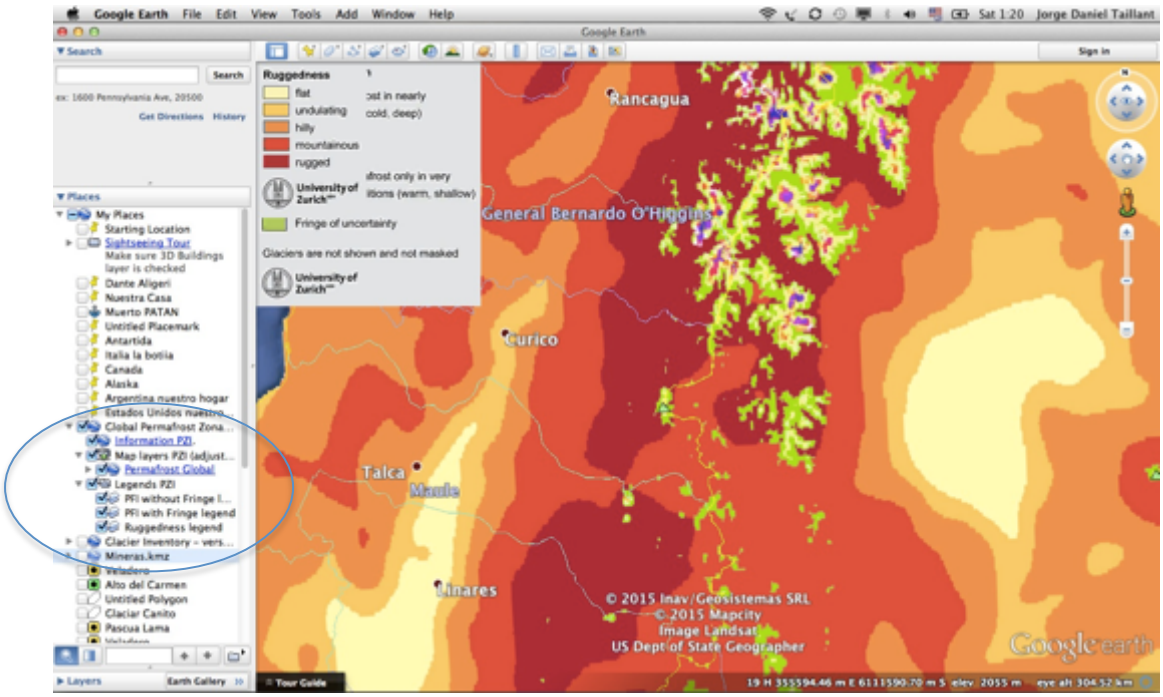
This work is tedious and very imprecise. But recently there is a more advanced technology available to identify the limits of the periglacial environment. It provides a very simplified and automatic tool that allows for the probabilistic estimate of the presence of frozen grounds anywhere on the planet! It is a model developed by the University of Zurich that runs on Google *earth!* This model determines the probability of finding frozen grounds at any given point on the planet, that is, it is an automated *global permafrost model*. The program can be freely and easily downloaded to your computer. All you need to do is download the model document and run it from your local drive. Here is the link:

http://www.geo.uzh.ch/microsite/cryodata/pf_global/ [17]

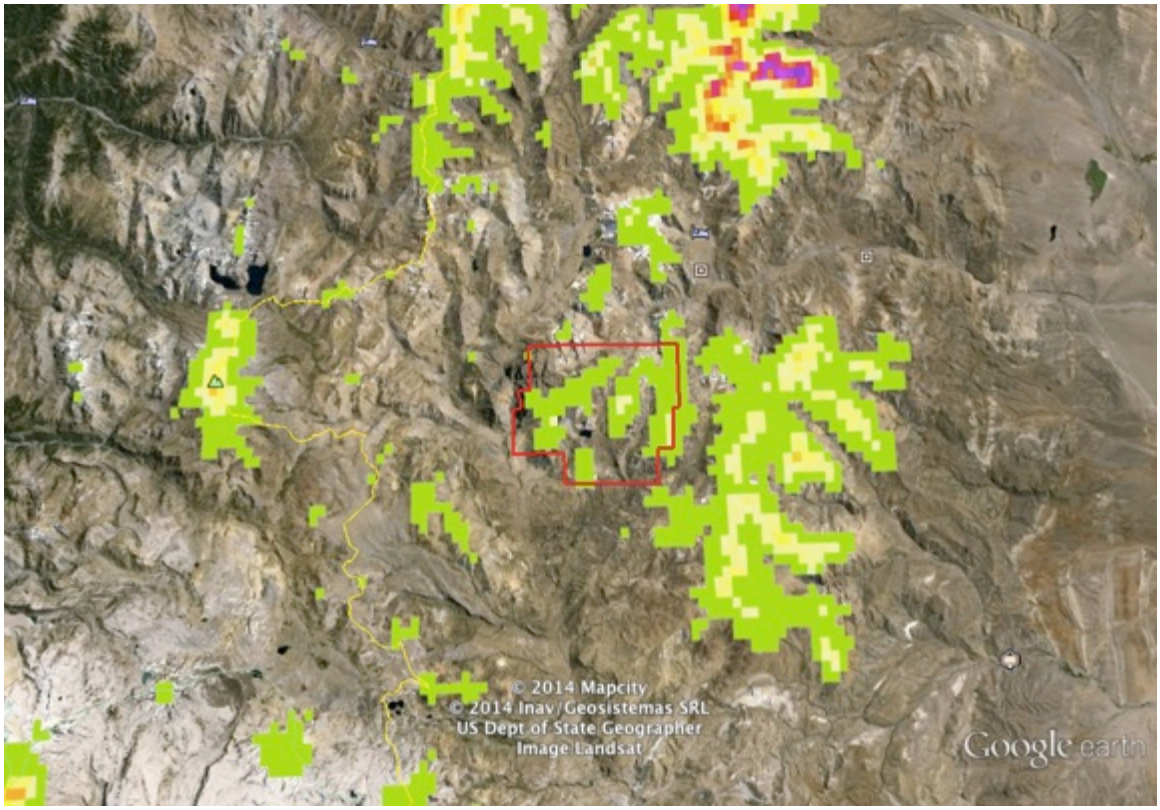
The file has an extension *".kmz"*, which are Google *earth* visible documents. It's simple and easy to use. Simply download it, unzip and open in Google *earth.* Once the file has been opened in Google *earth*, Google *earth* will always have the permafrost model program

[17] You must download it to your drive, unzip and open the file while in Google *earth.*

available and ready to run. You need simply to check or uncheck the file boxes on the left side panel of Google *earth* to activate the permafrost modeling tool. See image below.



Utilizing this tool, we can check or uncheck the box that shows “ruggedness” (that which appears in red in the image). If we go to the Cerro Amarillo mining concession and run the model we see the image above. By unchecking the ruggedness option, we see the image below and here we can identify likely frozen grounds.



Mapping of probability of frozen grounds utilizing the University of Zurich Global Permafrost Model (we've added the Cerro Amarillo concession polygon in red).

This image reveals lots of useful information as we try to analyze the Cerro Amarillo concession area for glaciers and periglacial environments. The red zones are areas with extremely high probability of finding permanently frozen grounds. The green and yellow areas are areas where there might be frozen grounds if the conditions are right. In the case of the yellow areas, there is probability of finding frozen grounds if the necessary conditions are given (South facing slopes or slopes in the shade for most of the day), while green areas are areas of uncertainty where more information is necessary.

It's important to clarify that *this model does not tell us if these grounds contain ice or not*. To determine ice presence, we need more information. Nonetheless, this doubt over ice presence, should not lead us to presume that there is no ice, but rather precisely the contrary. If we are carrying out a study over the presence of ice, the model is pointing us to where we are likely to find it, presuming the conditions are right. As such, we must take a precautionary approach to the issue, and considering that in this case, no one has done a permafrost map for the area, we must take these green and yellow area as a baseline to carry out our more detailed assessment. In this case, we can use the yellow and green areas to point out the places where studies are necessary to determine temperature and ice content.

One indicator that will indicate the presence of hydrologically rich frozen grounds is the presence of rock glaciers in the area or of solifluction (creeping frozen ground). If we see such frozen forms in the area through satellite images, we can conclude that there are hydrologically rich frozen grounds present, at least at those sites. The presence of these additional clues helps us conclude without a doubt that we are in the presence of ice-rich periglacial resources.

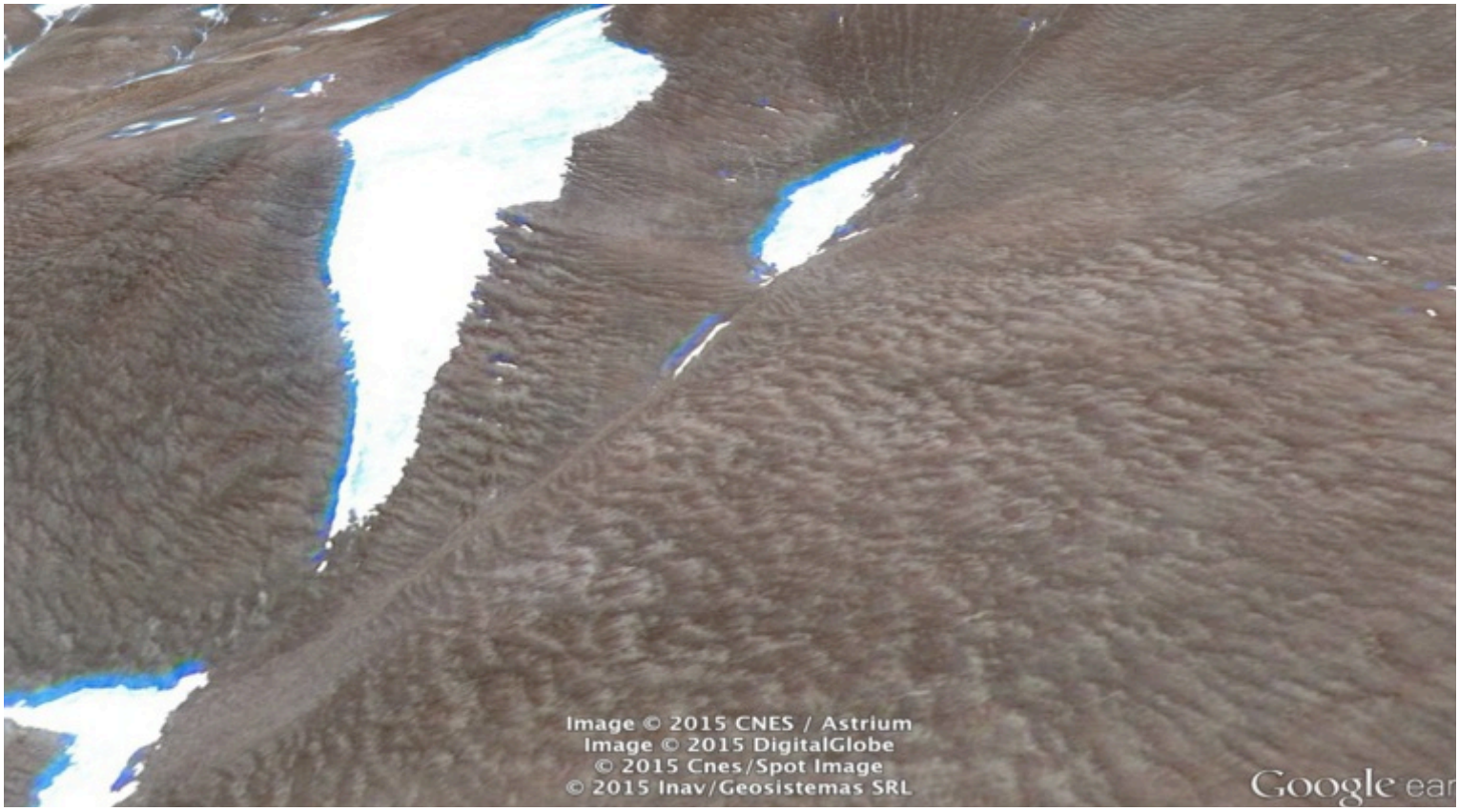
Active rock glaciers, for example, are clearly visible in high-resolution satellite images, due to the fact that the physical movement of rocks on and in the glacier leave distinct patterns on the surface of the Earth. Particularly during summer months, with no seasonal snow cover that could cover the patterns made by a rock glacier, rock glaciers are especially noticeable. In some cases, we can also see other cryological resources in satellite images, such as ice-saturated creeping permafrost grounds. These look like wavy wrinkles on the surface of the

earth, however this is unusual and one generally needs to conduct a site visit to determine the presence of ice-saturated creeping permafrost.

Below is an image of ice-saturated creeping ground. It appears to be a melting surface rock layer. In this case, for a technical expert familiar with the characteristics of permfrost areas and periglacial environments, this ground is effectively visible in satellite images. Note the same site in a satellite image taken from Google *earth.* See: 29 01 07.23 S, 67 50 30.18 W. You can see this moving, creeping ground, right on your smartphone!

Photo of surface wrinkles (ice-rich creeping ground) in a periglacial environment. (Photo: JP Milana)

The same location viewed in Google *earth*, confirms that you can see creeping ground in satellite imagery.



The automatized global permafrost mapping model developed by the University of Zurich is like any other theoretical model. It is a tool that helps us *estimate* the probability of finding frozen grounds at a given site. But the model is not definitive without accompanying field visits and/or without other accompanying evidence, such as the presence of rock glaciers, which are one of the possible elements of the periglacial environment. Active rock glaciers, are by definition, saturated in ice and are in the periglacial environment. In our own experience and use of the global permafrost model, and taking into account the more than 3,000 glaciers and rock glaciers that we have inventoried, we have yet to come across a case where the model did not predict that a glacier or rock glacier could have been present where we found it. This opens the way for us to consider using the model inversely, that is, we are safe to say that glaciers and rock glaciers, if present, will be where the model predicts they will be. The direct correlation of the permafrost mapping with rock glaciers, is a strong indicator that we can use the model constructively to help us predict glacier and rock glacier presence.

What the global permafrost model allows us is to identify the "probability" of finding ice and with additional help, such as the analysis of high definition satellite images, or with a possible site visit, we can underpin the model's information for a more precise scoping for glaciers and periglacial areas. We can then use this information to order the necessary studies and glacier/periglacial inventories to determine risks and impacts to cryogenic resources from industrial and other activity.

Once we know where glaciers and periglacial environments are likely to be, we can then command a company to carry out inventories and studies in order to protect the hydrological resources that may be found in those environments.

Returning to the mapping of permafrost by the model at the Cerro Amarillo site, we can conclude the following:

- There is ample possibility of finding frozen grounds in the mapped area; this is later confirmed by the identification of active and maybe inactive rock glaciers inside the concession area (more on that later);
- There is the probability or at least the possibility of finding ice-saturated frozen grounds in areas where there may not be rock glaciers visible;
- There are at least three areas in the concession with high probability of finding frozen grounds (yellow areas);
- The majority of the areas that *Meryllion Resources* has targeted for future drilling are in areas where there is at least the uncertainty over the presence of frozen grounds (green areas);
- *We do not know* for certain without the necessary studies if there is ice in the potentially frozen grounds of the green and yellow areas;
- *We do know* with absolute certainty that there are ice-saturated frozen grounds where we identify active rock glaciers;

A debris-covered glacier of the Central Andes reveals massive ice interior. Photo: Mariano Castro, IANIGLA

Rock Glaciers

The most notorious element (or characteristic) of periglacial environments are undoubtedly *rock glaciers*. The first point of clarity is that a rock glacier is one element of the periglacial environment, but it is not the only one. This means that, *if we identify an active rock glacier*, we are in a periglacial environment. A corollary to this presumption is also true, which is that *there might be ice-saturated periglacial environments, without the presence of rock glaciers.*

This is an important point, and when we get into the discussion over Argentina's glacier inventory currently underway, we must be careful not to divert our focus from areas of the periglacial environment, which might be rich in ice (and therefore protected by law), but that are not identified in the national glacier inventory! In fact, this is very likely to happen!

Rock glaciers are glaciers that are covered and mixed with fine and course rock material, and which have similar dynamics to normal uncovered glaciers. They are massive bodies of ice and rock that flow downhill just a normal glacier flows downhill. They slide down mountainsides due to their lubricated bases and due to their weight. They can hold colossal amounts of water, with their volume being between 50% and 80% ice.

There are also smaller rock glaciers, for example rock glaciers that form at the base of a very inclined slope (talus rock glaciers). These can be very short in length ranging from 100 to 200 meters (320 to 640ft) as measured from the base of the mountain, but which may follow the contours of the mountain for several kilometers, making them glacier giants! The most surprising thing about these elements of the cryosphere is that they are practically invisible for those people in their vicinity of they are not trained to see them. You could be standing on more than 50 meters (160 ft) of vertical ice, and if someone didn't point it out to you, you wouldn't know it!

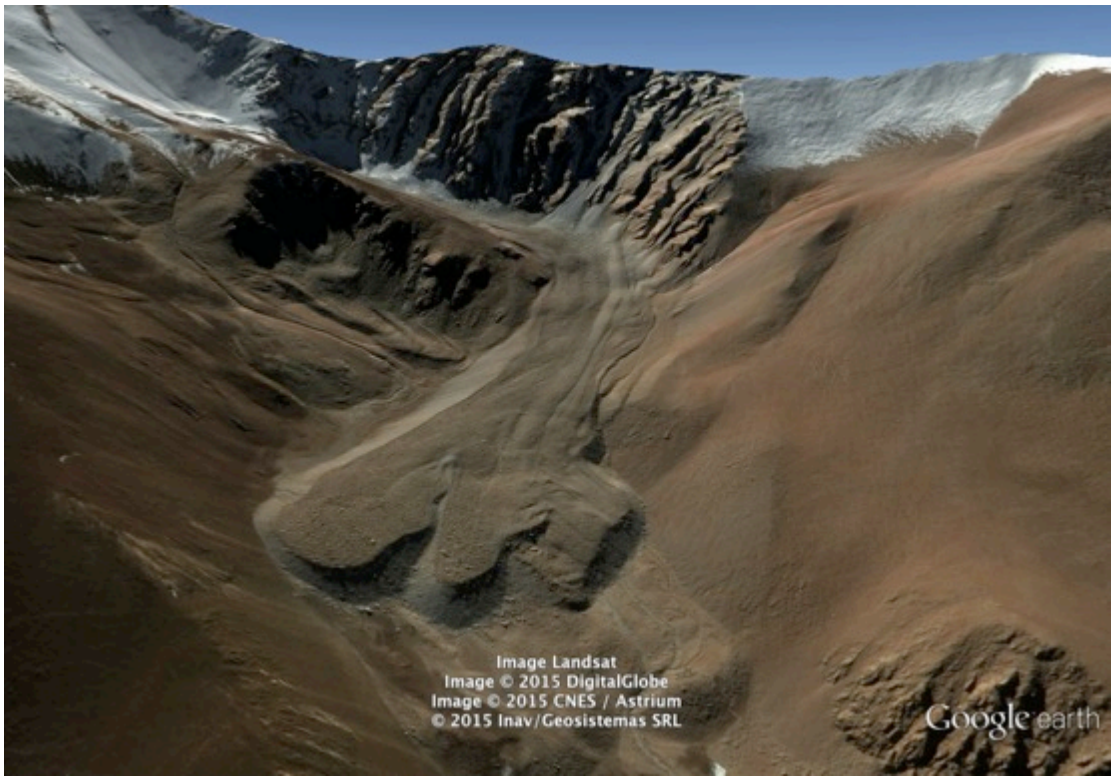
For the most part, rock glaciers are completely covered by rock debris, while another type of rock-rich glacier, called specifically a *debris-covered glacier*, can show core ice, as in the picture above. It may be a bit confusing to the periglacial environment novice, but basically there are rock glaciers that are fully covered by rock and debris-covered glaciers that oftentimes show their ice core. And to make things even more complex, there are also *debris-covered glaciers* that transform into *rock glaciers* at a single site. A trained eye can spot the difference! We will not go any deeper into this distinction in this report, but it is a fascinating, and largely unknown world of ice up there in the mountains!

Here are some characteristics to assist in the identification of a rock glacier. Some of these may apply to *debris-covered glaciers*, although we are focusing on the *rock glacier* in the list:

1. They flow through an inclined ravine, and appear to be frozen lava from a volcanic eruption;
2. They form crevasses or folds on the earth's surface due to their advancement and unstable state;
3. They accumulate and order rocks that have been pushed up onto the surface from the glacier's core hiding all ice;
4. They oftentimes take the form of a tongue or lobular form at their lowest points;
5. Their lowest points ends in an abrupt and straight 30-40 degree angle;

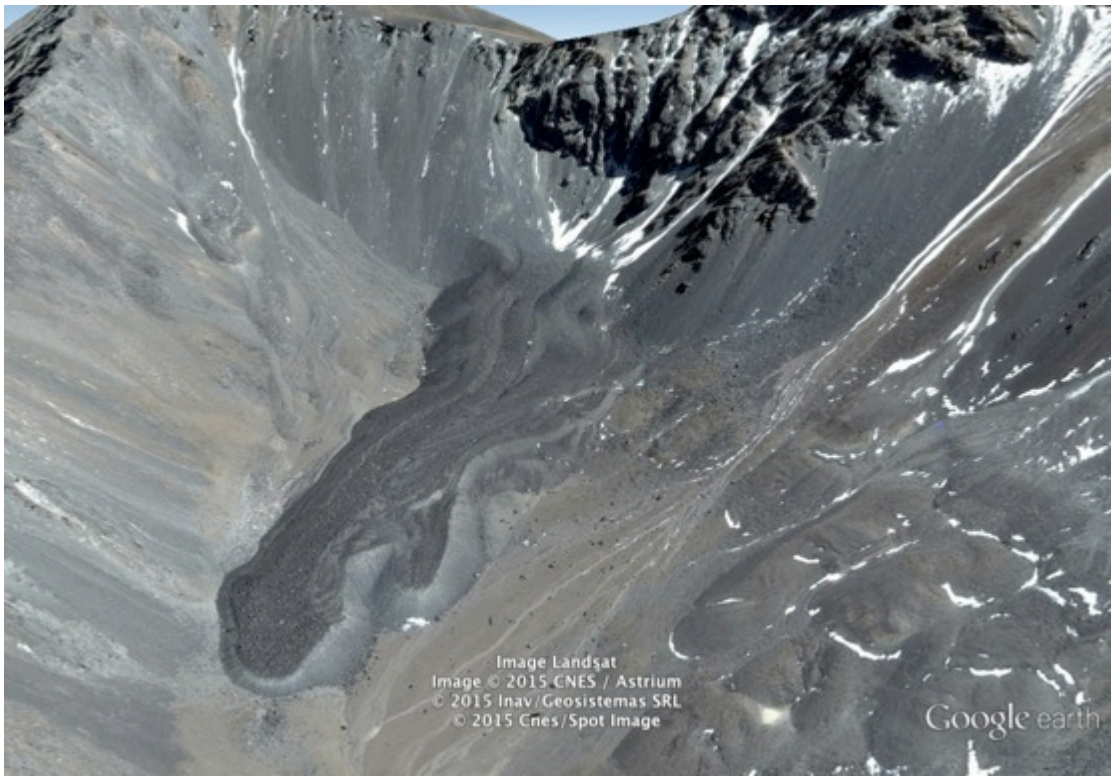
Let's take a look at the following images. These are all active ice-saturated rock glaciers in multiple areas of Argentina. En each case, the reader can visit these rock glaciers on Google *earth* (or on your smartphone in satellite mode)! Once the image is loaded, you may have to zoom out or in to see the glacier in its entirety.

a) Rock glacier in Salta Province (25 00 40 S, 66 21 26 W)



b) Rock glacier in San Juan Province (30 29 57 S, 70 09 09 W)

c) Rock Glacier in Tucuman Province (27 13 16 S, 66 04 35 W)



Are there rock glaciers or debris-covered glaciers in the Cerro Amarillo mining project concession area? If so, can we see them on satellite images?

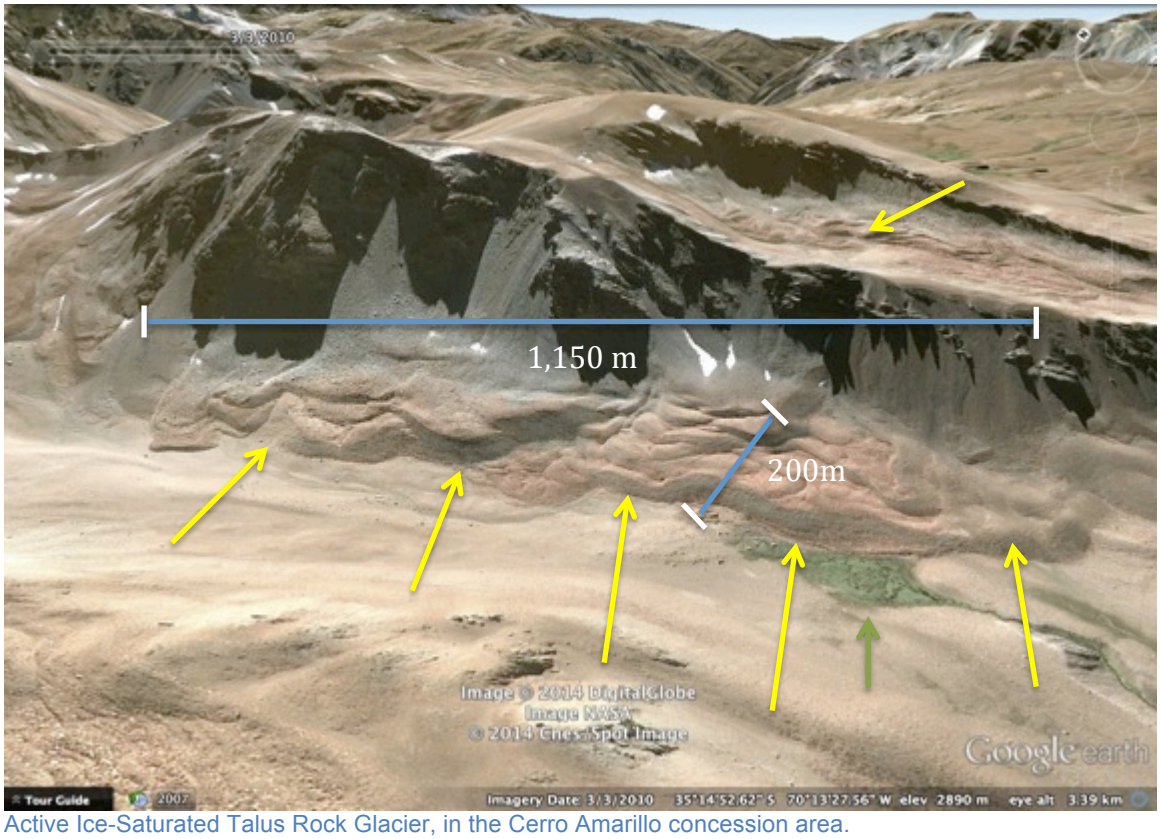
In the following image, visible at: 35 14 52 S, 70 13 21 W

taken from Google *earth*, we see a hidden active rock glacier in the North Western end of the Cerro Amarillo concession. We say “hidden” because the image that loads on Google *earth* was taken before the seasonal snow had melted away. This hides the typical characteristics of a rock glacier, such as the lobulated form, or the folds and crevasses, or the frontal 30-40 degree straight angle cut of the lower tip of the glacier. Other times, the rock glacier is so prevalent, that even snow cover cannot hide its’ presence!

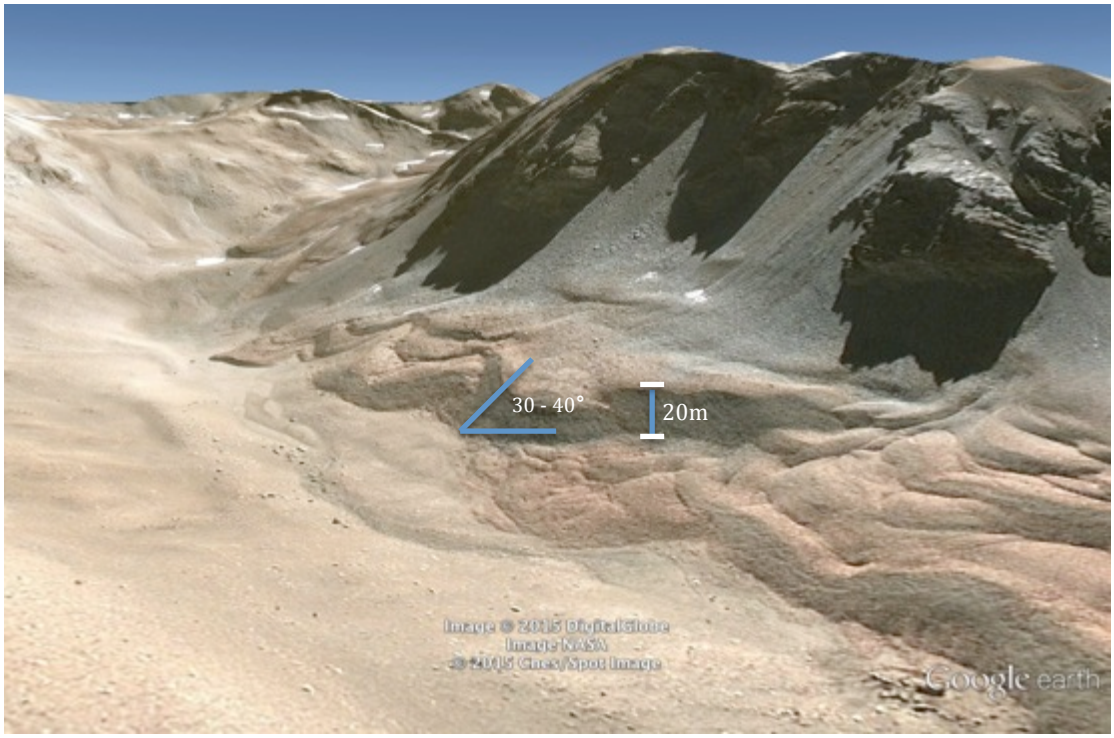
However, we can get around this visual difficulty by utilizing Google *earth’s* time feature (the “historical imagery” feature on the icon the task bar)—note that map programs on smartphones do not offer this feature!

With the *historical imagery* function we can see various satellite images from different years of this same site. If we slide the bar on the timeline that appears we can move around from image to image. If we choose the image from 3/3/210, we can clearly see an active rock glacier at the foot of the mountain incline. It appears as a flowing body of rock with crevasses and folds, with the typical 30-40 degree frontal cut. We might have otherwise presumed this was the remnants of a past volcanic eruption, but if we look around the area with Google *earth*, we see that clearly there are no volcanoes in this area. This rock flow is being produced by an active rock glacier! Also in the ravine just behind this one, we can see another active rock glacier descending the slopes. The folds and crevasses on the rock surface of the glacier are indicators that this indeed is an active rock glacier.

In the next image we zoom in to see the rock glacier in its entirety. The yellow arrows point to the rock glacier.



Active Ice-Saturated Talus Rock Glacier, in the Cerro Amarillo concession area.



Another angle of the talus rock glacier in the Cerro Amarillo mining project concession area.
We can see the typical frontal angled (30-40 degrees). This rock glacier is some 20m thick (65ft)!

Although this talus rock glacier may appear to be small in size, it is more than a kilometer long (.7miles) and is more than 200 meters (650ft) wide, with a total surface area of 200,000m^2 (that's 240,000 yard^2) or nearly 20 hectares (50 acres). The glacier is approximately 20 meters thick (65ft)! Note that at the foot of the rock glacier we see a *vegas* system (see the green arrow). This is a high mountain wetland system typical of the high Central Andes region. This vegas is irrigated and thrives because of the permanent

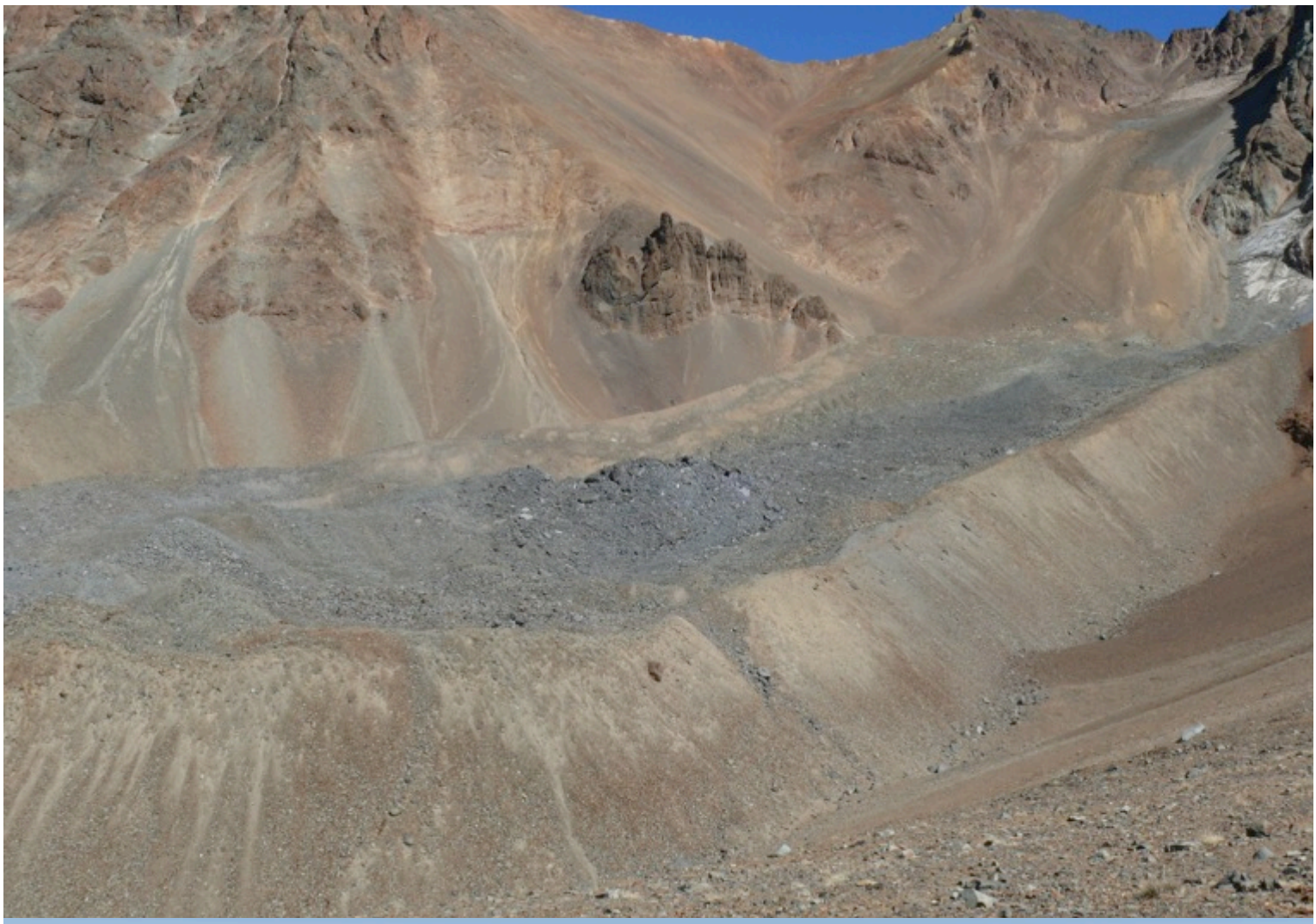
hydrological contribution in the form of glacier melt water of the rock glacier. These vegas systems are critical water reserves for local species.

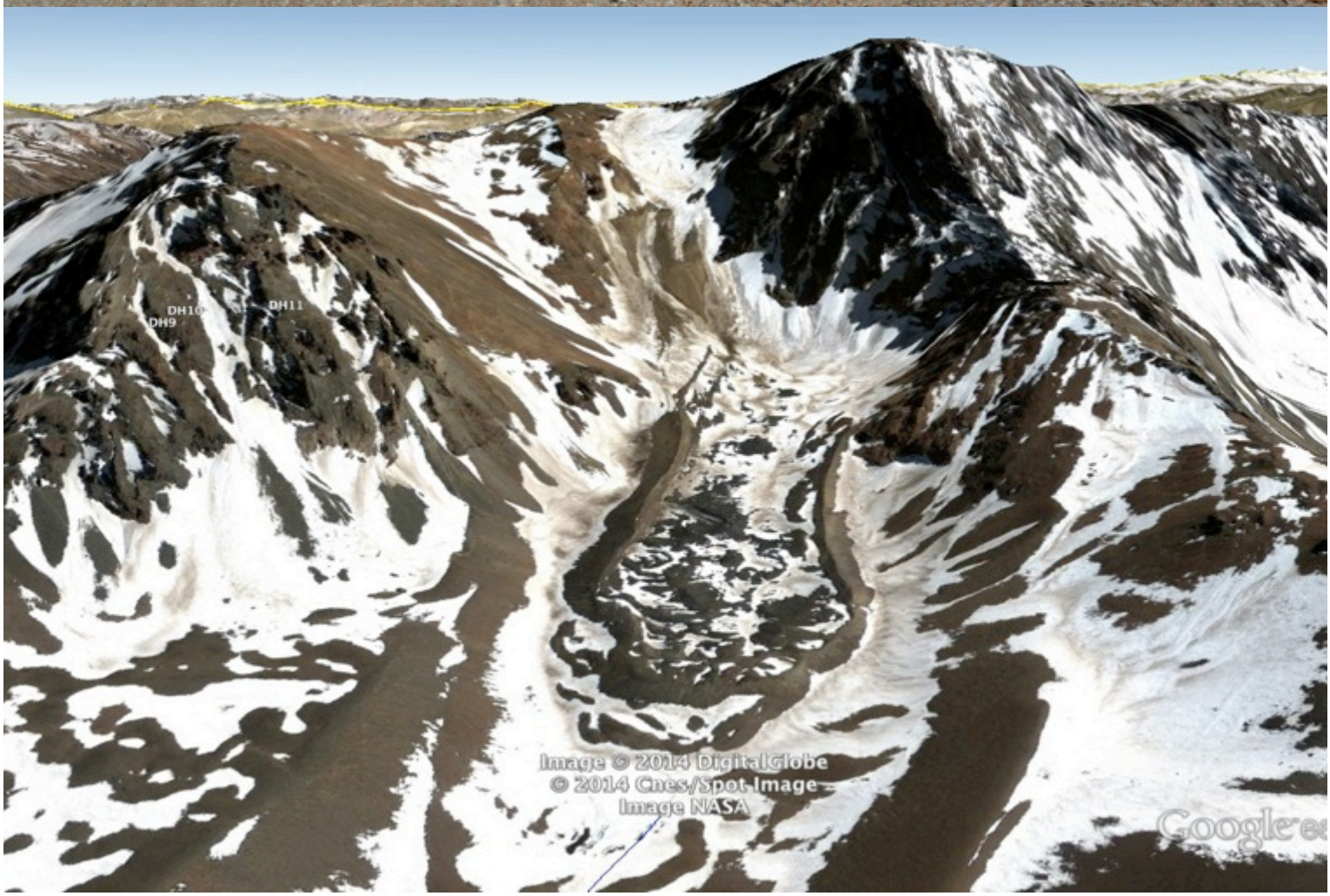
Can we calculate the hydrological content of this rock glacier? If we make a conservative estimate that the rock glacier contains about 50% ice by volume (they usually contain up to 70 or 80% ice), this means that its hydrological content can be derived as follows. There is approximately 1,000 liters of water in a cubic meter of ice. 200,000 (surface area) X 20 (thickness) X 1,000 (liters per square meter) = 4,000,000,000 (that's 4 billion liters of volume) X 50% (we're conservatively guessing only half of the volume is water) = 2,000,000,000 liters of water (that's 528 million gallons of water). If we distribute this water amongst the Argentine population (40,000,000 people), that gives each Argentine 50 liters of water. People consume about 2 liters of drinking water per day. So if we were able to bottle this talus rock glacier, the entire Argentine population could drink water for nearly a month (25 days to be exact).

When we see a rock glacier in mid summer, there generally does not appear to be any ice anywhere in sight. But lets look at the interior of a subterranean glacier. Below is an image of a debris-covered glacier that has broken up, exposing its interior ice. We note the thick debris cover at the surface of the glacier about 2 to 3 meters thick (6.5 to 10 ft). Then below we see a massive ice core. There is a person standing on a boulder in front of the glacier, so that we can understand the scale of this ice body. Generally, we cannot see the ice of a rock glacier. A fully developed active rock glacier is far below the uncovered glaciated areas of a mountain, and so exposed ice will not survive the heat. This debris-covered glacier, which is closer to glaciated areas, permits us a window into the realms of subterranean ice.

Debris-covered rock glacier reveals massive ice core. See the person on the boulder for size reference.

Below we see two images, one real photo and another taken from Google *earth* of the same geoforms. We clearly can see a rock glacier descending the mountain slope. This rock glacier is in the heart of the Cerro Amarillo mining concession. The rock glacier is some 1,400 meters long (4,600ft) and some 400 meters wide (1,300ft) and is approximately 20-30 meters thick. We can see the typical angled (30-40 degrees) cut at the front of the glacier. You can see this glacier at: 35 19 46 S, 70 13 53 W. The snow cover in the image makes the rock glacier difficult to see in Google *earth* but the photograph we were able to obtain from the site is unquestionably a rock glacier!

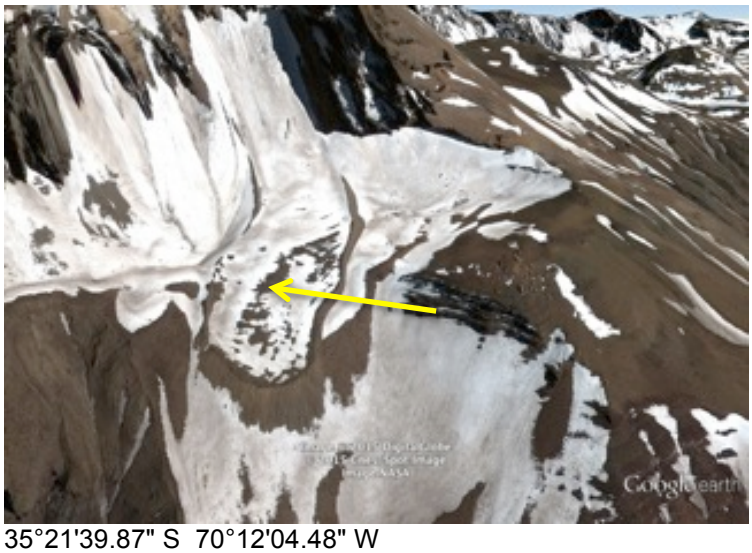




This is a rock glacier at the heart of the Cerro Amarillo project. We can compare the photograph above with the Google *earth image.*

Other images of rock glaciers in the Cerro Amarillo mining concession:

35°20'18.24" S 70°14'36.85" W



35°21'39.87" S 70°12'04.48" W

35°14'52.86" S 70°14'12.66" W

Active vs. Inactive Rock Glaciers

One of the debates that is presently dominating the mining sector (and which will surely come up with Cerro Amarillo) with regards to its potential glacier or periglacial environment impacts is the difference between the varying types of rock glaciers.

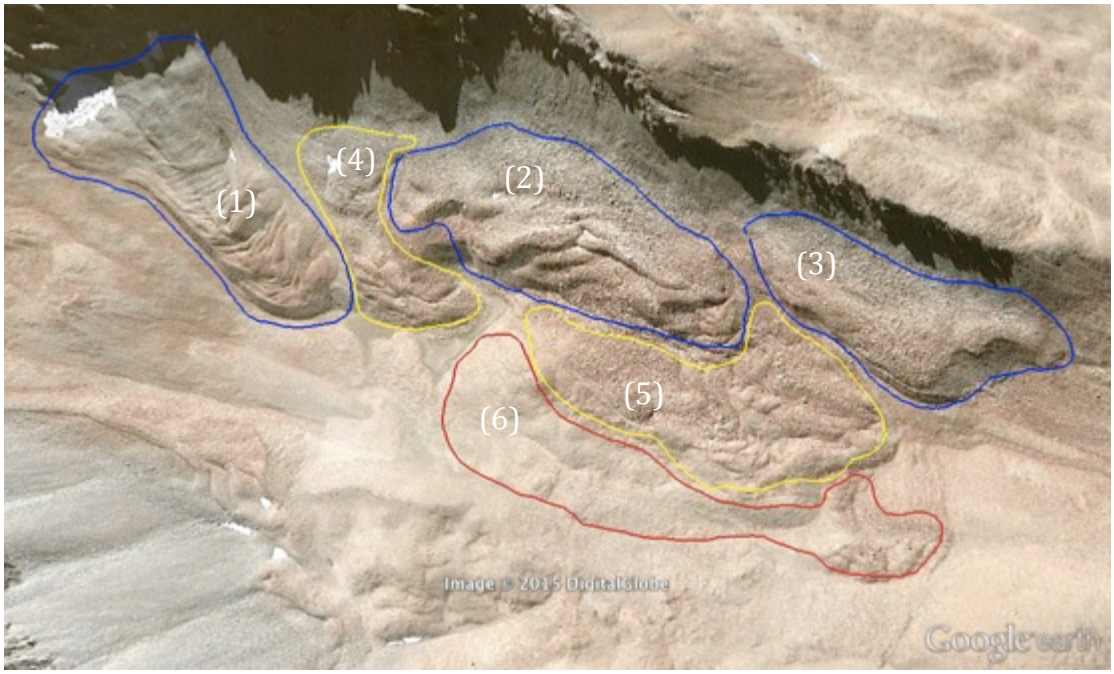
There are two basic and very important types of rock glaciers, on the one hand, "active" rock glaciers, and "inactive" rock glaciers. Argentina's National Glacier Protection Law does not distinguish between these resources in terms of protection, because essentially both are water reserves and both help regulate water basins, which are the two functions the glacier law aims to protect.

Some of the provincial glaciers laws (for example, the Glacier Protection Law of La Rioja Province)[18], make this distinction, based on the erroneous interpretation of the difference of the two types of rock glaciers. If the objective of the law is to protect the hydrological resource, or if it is to protect the basin-regulation function provided by the resource, then the distinction is unneeded, since both types of rock glaciers are important to each of these functions. We may have a discussion regarding the precise stage of evolution (or devolution) of an inactive rock glacier on route to becoming a fossil rock glacier (since at that stage it would no longer contain ice). That is, towards the end of the life of a rock glacier, the body practically has no remaining ice, but at that stage, the body would likely no longer appear in satellite images with the same characteristics of an active or inactive rock glacier, which in turn would mean that it would not probably appear in a glacier or periglacial inventory.

The technical difference between an active and inactive rock glacier has to do with *movement*, *ice content*, and the *health* of the rock glacier. In an *active* rock glacier, the glacier is actively moving forward (and for this reason we call it "active"). The ice body creeps forward because of its weight, base lubrication and its active dynamics. In an *inactive* rock glacier, possibly inactive as a result of global warming which is heating up the environment to a point where the glacier can no longer keep frozen, this movement is diminishing, until finally it stops altogether. The inactive rock glacier, in contrast to an active rock glacier, appears to be deflating. In many cases, this signals the beginning of the end of the rock glacier. But we should beware, this devolution of the active rock glacier into an inactive rock glacier, and eventually into a fossil rock glacier, is not a fast process, and in many cases can take many years, decades, and even centuries! For this reason, inactive rock glaciers continue to be important hydrological reserves that are also protected by law!

A last point worth mentioning is that although an inactive rock glacier might be in an irreversible phase of deterioration, the inactive rock glacier can provide a continuous flow of water into the ecosystem for many years before it completely disappears.

[18] See: http://wp.cedha.net/wp-content/uploads/2011/09/Ley-de-Glaciares-La-Rioja.pdf



Fossil, inactive and active rock glaciers... as seen in satellite images. Place of image: 35°14'55.52" S 70°12'41.96" W (inside the Cerro Amarillo mining concession)

The *active rock glacier* (with high ice content, generally between 40 and 70 or 80% of its volume), displays folds, crevasses and undulations that are clearly visible in satellite images. They typically end in a sharp angular cut of 30 to 40 degrees (see the blue polygons in the images, numbered 1, 2 and 3). The *inactive rock glacier* is a slightly smoothened version of the active rock glacier. It appears to be deflating (it may be depressed on its surface) and will show less vigor than the active version (see the yellow polygons 4 and 5). Finally *fossil rock glaciers* no longer display the characteristic evidence of folds and crevasses and undulations associated with active or inactive rock glaciers (see polygon 6 in the image). The fossil rock glacier is a remnant assortment of the rocks that were once being transported by the active rock glacier. The rocks are left where their motion ceased. We can no longer say that we can clearly see the folds, crevasses or undulations typical of an active rock glacier. Even the *near-*active characteristic of the inactive rock glacier are also gone.

We should emphasize that the certainty over the presence of active, inactive or fossil rock glaciers, goes from high to low in this order. We can more quickly and more easily identify active rock glacier in satellite images, and we do it with much more precision and certainty. In the image, polygon number (1) is undoubtedly an active rock glacier and we can say this because the folds and crevasses are clearly visible. There is clear evidence of movement. These typical characteristics make the identification of active rock glaciers very straight forward on satellite images. Polygons (2) and (3) are also surely active rock glaciers, although their movement is a little bit less pronounced. Could they be “inactive” rock glaciers? Maybe, although polygon (2) has some very clear movement occurring; a bit more than (3). The frontal angled cut at 30-40 degrees of rock glacier (3) is an indicator for us that we are effectively looking at an active rock glacier.

When the rock glacier passes from activity to inactivity, we may still see some of the typical characteristics of an active rock glacier, the folds, the crevasses, etc. Polygons (4) and (5) have these folds and crevasses, however, we note that they are somewhat less defined, and that the sharp front angle of 30-40 degrees, may be rather smoothened out. For these reasons, we can speculate that this cryogenic geoforms has transgressed into an “inactive” phase.

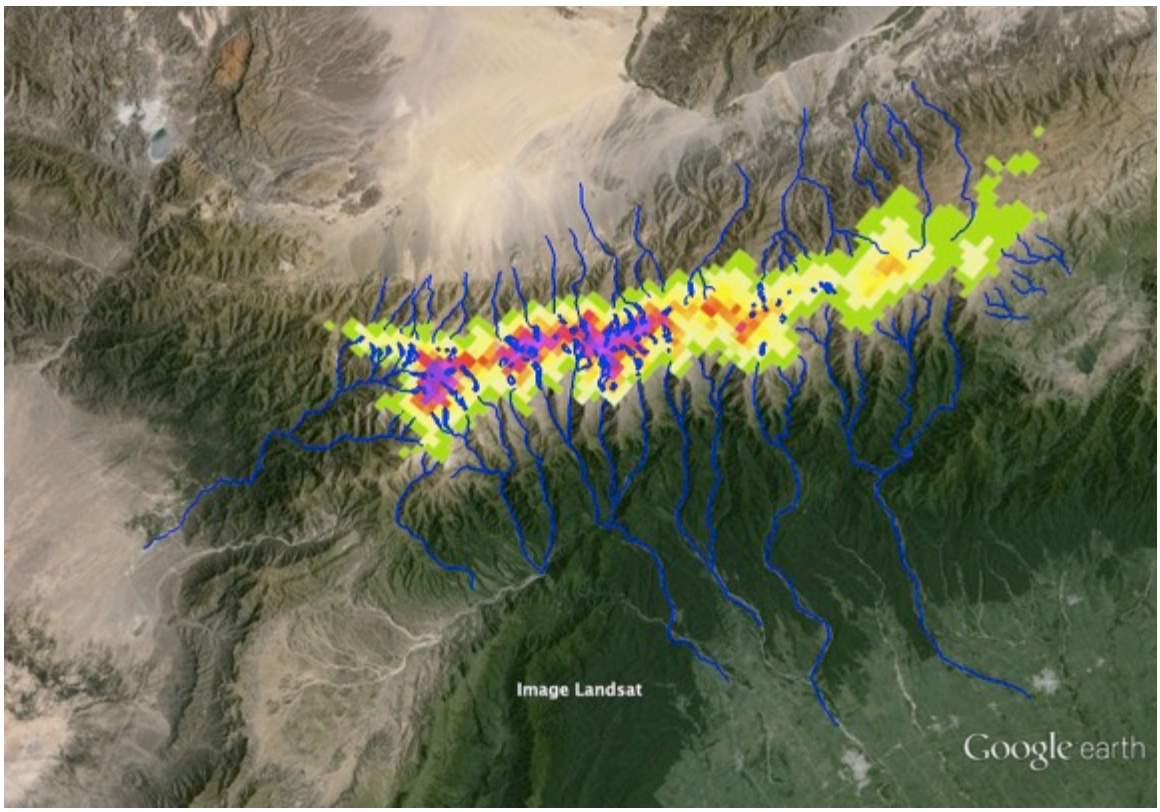
As the inactive rock glacier goes from inactivity to fossil state, it becomes more and more difficult to distinguish the typical characteristic features that distinguish an inactive rock glacier from a fossil rock glacier in satellite imagery. In the yellow polygons (4) and (5), we suppose there has been a reduction of movement, but we cannot be absolutely sure if there is still

activity in the rock glaciers. When we see the remaining rock deposits in polygon (6), we can suppose that there was once an active rock glacier present, but we can no longer find the distinguishable characteristics that show present movement.

Water Contribution of the Periglacial Environment

Ice-saturated periglacial environments, and rock glaciers (which are an element of the periglacial environment) are critically important hydrological reserves contributing enormous quantities of water to the ecosystems below them. Recall that the periglacial environment captures humidity in the environment (deriving principally from snow) in the form of ice, holding it in its interior, whether on the surface or deep under the earth in the form of a glacier or rock glacier, such as the rock glaciers that we saw in the previous images.

In the next image we see the Aconquija Mountains, which form the natural border between Catamarca and Tucuman Provinces in Argentina. These mountains stretch above 5,000 meters above sea level (16,400ft). They have extensive periglacial environments.



Relationship between frozen grounds, rock glaciers and rivers in the Aconquija Range
coordinates: 27°12'31.44" S 66°05'49.08" W

If we utilize the permafrost mapping tool offered by the University of Zurich, we can map out the frozen grounds of the mountain. While the model does not permit us to see ice that may lay beneath the surface of the earth, we have taken the trouble of also mapping out all of the water ways that are born in the high altitudes of the mountain. This is also where the rock glaciers are located. In the image we have also mapped the rock glaciers. There are some 400 of them! In most cases, the rivers stem directly from rock glaciers.

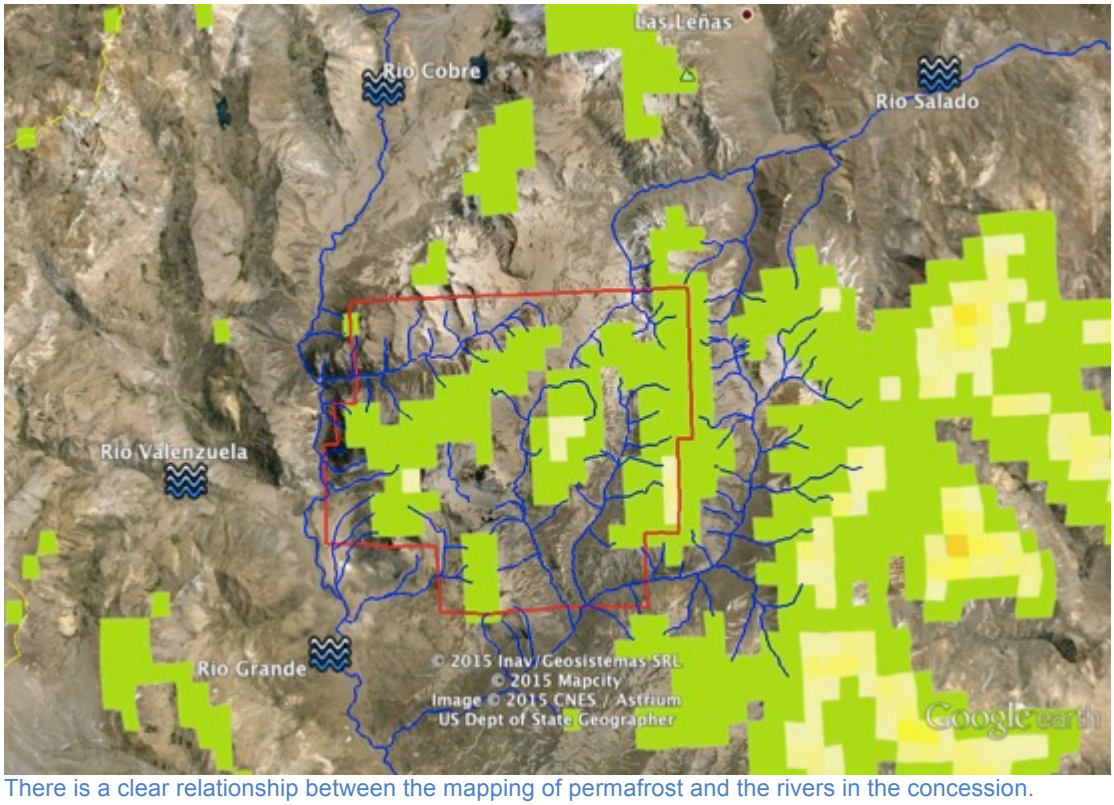
In this image of the frozen grounds of the Aconquija we can deduce three important facts:

1) In the mapping of frozen grounds, red and puple zones are almost certainly frozen the majority of the time, yellow areas have high probability of being frozen under favorable conditions, while green zones are suspects for frozen grounds.
2) Rock glaciers are the blue polygons;

3) All rivers of the mountains are born from the ends of the rock glaciers, which leads us to conclude that the rock glaciers are saturated in ice and contributing actively to the waterways;

This interrelationship is quite logical. In summer months, the water that we might finding surging from natural springs originates in the periglacial environment. The water contribution of the periglacial environment is unquestionable.

If we analyze the area of the Cerro Amarillo concession in the same way, and we map out the waterways and their relationship to the principal rivers of the region, we see a very similar map. In the following image, we have traced all of the waterways in each one of the ravines of the Cerro Amarillo concession. We can clearly see how all of the higher areas where we are likely to find ice-saturated frozen grounds, according to the University of Zurich model, are the birth sites of the various river systems in the concession. This is not a coincidence. The water comes from the periglacial environment!



There is a clear relationship between the mapping of permafrost and the rivers in the concession.

In the following image, taken in February of 2012, when there was no winter snow left anywhere in the Cerro Amarillo concession, we see water streaming from the base of a rock glacier. To the right of the image we see the front of the rock glacier, with a typical 30-40 degree angle cut.

Melt and water accumulation at the foot of a rock glacier in the Cerro Amarillo mining concession.
Photo location: 35 20 00 S, 70 13 44 W; Source: Daniel Warenica, 2012

In the next image, taken at the same site, but facing in the opposite direction, we see the water runoff of this rock glacier. We can see a rather active stream flowing forth, created by the rock glacier and periglacial environment above.

Stream formed by melt of a rock glacier in the Cerro Amarillo mining concession.
Place of photo: 35 20 00 S, 70 13 44 W; Source: Daniel Warenica, 2012

More surprising still are the following two images of the Laguna del Cajón (also taken in February). This lagoon forms at the base of the mountain ravine, at the heart of the Cerro Amarillo mining concession. While we can argue that this lagoon forms due to melt water from seasonal snow, at this stage of the year, the snow has already melted and yet we see a very significant water flow rate coming from the lagoon. This is undoubtedly due to the permanent and sustained contribution of melt water to the lagoon. However there is no more seasonal snow to sustain this very significant flow. So where is the water coming from? It is coming from the melting of the periglacial environment above.

The lagoon, *Laguna del Cajón*, formed by the melting of periglacial environment.
Place of the photo: 35 19 30 S, 70 12 16 W; Source: Daniel Warenica, 2012

Strong current flow after the end of snowmelt suggests the lagoon is fed constantly by a melting periglacial environment.
Photo location: 35 19 30 S, 70 12 16 W; Source: Daniel Warenica, 2012

Deniers of the Hydrological Value of Periglacial Environments

There are professionals and academics out there, principally related to, or working for the mining sector, that deny the hydrological value of the periglacial environment. In fact, a consulting firm called BGC which works as a contractor for Barrick Gold Corporation[19] and its Pascua Lama project, was contracted by the Professional Mining Association of San Juan Province with the task of touring Argentine and Chile to talk about periglacial environments. I attended their lectures and one of their main messages to audiences was denying the hydrological value of rock glaciers.

The argument postulated by BGC on this tour was that since rock glaciers are in equilibrium with the ecosystem, they have no positive hydrological impact. That is, all of the water/snow that enters the rock glacier in the wintertime, exits the rock glacier in the summer time, and so in relative terms, the hydrological contribution of rock glaciers to ecosystems is a zero-sum exercise. Additionally they argue that the hydrological contribution of rock glaciers is minimal.

These affirmations by BGC are merely theoretical interpretations, not substantiated by data, and furthermore, they are void of all logic. In the first place, global warming is continuously causing a rise of mountain temperatures, melting glaciers all over the world, including rock glaciers, which are located in the warmer portions of the periglacial environment. We can imagine that the latitudinal line at which everything freezes and remains frozen on the mountain (the average zero temperature line) is progressively moving higher. The frozen mountain is effectively in a slow melt phase. This means that the periglacial environment and all of the geoforms in the environment are slowly and progressively melting from the bottom up. We can imagine that the periglacial environment (which is below the glaciated environment) is pushing the glaciated environment upwards. While uncovered glaciers higher up are melting and move “up the mountain”, so do periglacial environments.

This is a troubling situation, where frozen hydrological resources of high mountain environments are constantly pushing upwards until they have nowhere else to go. Eventually they will all melt. First the glaciers will disappear, and then, the periglacial environments will also melt away. This will dry up rivers during months with no precipitation, and the slow and steady glacier and periglacial melt that once fed rivers during dry months, will be no longer. These rivers will become seasonal rivers, wet only during melt seasons.

Due to climate change, the periglacial environment, and the rock glaciers in these environments, are not in equilibrium as BGC suggest. They are melting. Their lower limits are losing hydrological content. They are contributing net positive sums of water to our ecosystems. Because they are melting, they cannot be in equilibrium, as some would have us think.

One other issue that needs to be pointed out is that the real and most significant underlying value of glaciers and periglacial environments is not *the amount of water they contain*, but rather *the rationing of water* to lower ecosystems that they carry out. That is, glaciers, rock glaciers, and other periglacial features capture water in the form of ice, and then release it slowly through the warm and drier months, when there is no more precipitation to feed water into ecosystems. The “slowing” of the water melt is the most important natural function of these resources, and it is why Argentina’s Glacier Protection Law protects the resources!

Glaciers and periglacial environments retain water and release it after all of the seasonal snow has melted away. For this reason, it’s not important if these environments have zero-net hydrological contribution to the ecosystem. It is the rationing function over time that is important.

Another argument against these unfounded affirmations by the consultants working for the mining sector is that they do not have reliable scientific data to sustain their affirmations about the supposedly minimal hydrological contribution of rock glaciers. Rock glaciers are a fairly

[19] The acronym “BGC” of the consulting company has no relationship to the acronym of the company, **B**arrick **G**old **C**orporation. The similarity is a mere coincidence.

new discovery in science, and there is very little historical data to measure their dynamics, including their hydrological contribution to ecosystems. While you can stand at the end of a rock glacier and measure the stream flow as you would out of a tap, very little is known about what is happening underground, how the melt water enters subterranean channels, and gets to mountain aquifers. Periglacial environments are in obscure and inhospitable places, and very little is known about how they intermix with hydrological systems. These are vast and complex expanses of land in far away places. Their study and measurement is no easy task and has not been fully, or even substantially, documented.

If we consider that the whole mountain is working like a sponge, absorbing water that comes from seasonal snow, that the mountain is freezing and thawing and re-freezing and re-thawing this ice/water at various times of the year, which could be in periods spanning several months, or in weekly cycles in a given month, or from day to night, or even hour to hour, minute to minute or even second by second, that is … water may freeze one minute, thaw the next, and then refreeze a minute later, we can surely realize that actually measuring this complex dynamic in an entire mountain across hundreds of kilometers is practically an impossible task.

What we certainly cannot doubt however, is that when the winter departs, until the cold returns, the lower limit of the periglacial environment is in a continuously melting state, releasing its' hydrological content into the ecosystem below. The photos published in this report taken at the lagoon in the Cerro Amarillo concession, and below the rock glacier nearby, are clear evidence that periglacial areas are significant contributors to the hydrological basins below them. How much they contribute, we may never know.

Mining Impacts to Glaciers and Periglacial Environments

Mining is an activity that is highly invasive to the environment and even more so for glacial and periglacial environments. It is for this reason that the Argentine National Glacier Protection Law categorically prohibits mining and hydrocarbon activity in glacier and periglacial areas.

Due to ignorance and/or to the negligence with regards to the presence of glaciers, rock glaciers and ice-saturated frozen grounds (permafrost), mining operations in high mountain environments of the Central Andes have caused and continue to cause significant impacts to glaciers, rock glaciers and to periglacial areas.

If the reader would like to see some of these impacts, CEDHA has produced numerous reports to show this impact, including:

- Impact to Rock Glaciers and Periglacial Environments by the Filo Colorado (Xstrata Copper) and Agua Rica (Yamana Gold) mining projects [20]
- Impacts to Glaciers and Periglacial Environments at El Pachón (Xstrata) [21]
- Barrick's Glaciers [22]
- Glaciers and Mining in the Province of La Rioja [23]
- Periglacial Environments and the Mining Sector in Argentina [24]
- Risks and Impacts to Rock Glaciers and Periglacial Environments by Los Azules (McEwen Mining) [25]

[20] see: (in Spanish Only) http://wp.cedha.net/wp-content/uploads/2011/09/Informe-Glaciares-de-Aconquija-Impactos-de-Mineria-Agua-Rica-y-Xstrata-Final-feb-18-2011.pdf
[21] see: http://wp.cedha.net/wp-content/uploads/2011/0s8/Glaciar-Impact-Report-el-pachon-xstrata-FINAL-english-version-may-23-2011.pdf
[22] see: http://wp.cedha.net/wp-content/uploads/2013/05/Los-Glaciares-de-Barrick-Gold-version-20-mayo-2013-ENGLISH-small.pdf
[23] see: http://wp.cedha.net/wp-content/uploads/2012/04/Glaciares-y-Miner%C3%ADa-en-la-Provincia-de-la-Rioja-English-Summary.pdf
[24] see: http://wp.cedha.net/wp-content/uploads/2012/11/El-Ambiente-Periglacial-y-la-Mineria-en-la-Argentina-English.pdf
[25] see: http://wp.cedha.net/wp-content/uploads/2012/07/Glaciar-Impact-Report-Los-Azules.pdf

The impacts of mining to glaciers and to periglacial areas is produced due to a number of reasons that have to do with the various stages of mining operations, including:[26]

- Due to the movement of grounds, displacing glacier ice or periglacial terrain, in a way that disturbs the structural equilibrium of the ice body; a mining vehicle that plows into a glacier or into a periglacial area can cause the slow or even sudden collapse of the entire ice structure, or the physical invasion into the ice body can change its' thermal balance and cause accelerated melting of all or part of the body;
- By impacting its' glaciosystem[27] (the natural elements that are part of, and that give origin to the formation and sustainability of a glacier or to a periglacial environment); if we modify a mountainside, changing wind patterns, which in turn affect the tendency of the precipitation of snow in a given place, we can alter the way the glacier system works, with the effect of impacting the sustainability of the glacier or of the periglacial system;
- Due to blasting, which introduced suspended debris particles into the air, which can cover a glacier, darkening it, and as a consequence, change it's reflective capacity (its' albedo), which in turn can cause the glacier to absorb more heat and thus melt faster;
- Due to vehicular transit and/or the use of machinery which burns fossil fuel such as diesel, which emits black carbon, which can soil the glacier surface and also change albedo and accelerate melting;
- Due to acid drainage produced by the contact of ice with soiled water or sterile rock removed/extracted/displaced by mining activity;
- Due to the introduction of exploratory mining roads used by mining companies which interfere with glaciers, periglacial environments and with glaciosystems;
- Due to the placement of weight on the glacier surface or on the surface of a periglacial environment altering the structure of the ice and its thermal balance. This can cause a degradation of the ice structure. An example that has occurred before is the placement of a sterile rock pile on frozen ice-saturated creeping ground. This is extremely dangerous as the instability can result in a massive rock slide;
- Due to the perforation of the ice with heavy equipment, with the use of lubricants and other contaminants that not only alter the structure of the ice but also contaminate the water supply.

In the following image we see a bulldozer plowing through a mountainside, introducing a new exploratory mining road. This could be periglacial environment.

If the driver is not advised that there may be ice-saturated periglacial environment present, she may not detain her advance and would as a consequence, plow straight through ice. This is actually common in mining operations occurring in periglacial areas.

[26] compare Brenning, 2008; Kronenberg, 2009; Brenning & Azócar, 2010
[27] for a definition of the glaciosystem see: http://wp.cedha.net/wp-content/uploads/2012/07/Definicion-de-Glaciosistema-version-1-febrero-2012-english.pdf

Workers for the Filo Colorado project in Catamarca (then Xstrata Copper, now Glencore Xstrata), recall that when they introduced the access road to the mineral site by bulldozing into the ground, they were surprised to encounter thick ice underneath the surface of the road. They were undoubtedly plowing into a rock glacier of the periglacial environment.

In the next image, at the *Altar* project (Stillwater), in San Juan Province, we see the indiscriminate introduction of mining roads directly into periglacial areas. These roads have cut, dissected and plowed straight into rock glaciers and other frozen grounds. The rock glaciers are identified as blue polygons. We can see this area very clearly, even on a smartphone! Simply open up your maps program, place it in satellite mode and go to:

31 28 55 S, 70 29 2 W

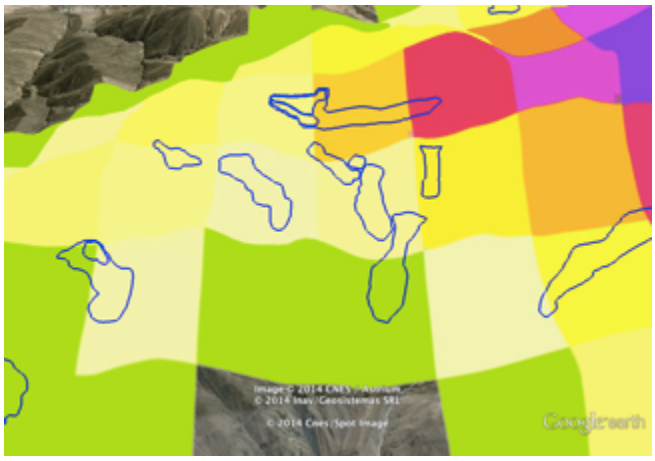
This is due to the lack of controls by the State over the company and the complete disregard by the company of these resources. Neither the provincial authorities of San Juan, nor the national government agencies responsible for monitoring mining companies are doing anything about this violation of the National Glacier Protection Law.

At the same time, we see how tools such as the global permafrost mapping tool offered by the University of Zurich can help the State identify this risk before it occurs. Had this tool been used for Altar, authorities would have known that there was a strong likelihood that the concession would contain rock glaciers or other legally protected ice-saturated frozen grounds. They could have insisted that the company carry out a mandatory glacier inventory and glacier and periglacial impact study to avoid this needless destruction of vulnerable protected hydrological reserves. The damage was completely avoidable.

The Altar project by Stillwater shows severe impacts to rock glaciers and periglacial environment

In the next image of the Filo Colorado mining project (today Glencore-Xstrata), we see the mining road introduced into the mountain by Xstrata Copper, simply to access the mining site for exploration activity. We see numerous bodies of ice (these are rock glaciers) cut by the access road. The company did not take any measures to protect these hydrological resources which are today protected by law. When Xstrata finished up its work at Filo Colorado it abandoned the area leaving its destruction behind with no remediation of the area whatsoever.

Xstrata Copper (now Glencore-Xstrata) impacted rock glaciers in Catamarca and then abandoned the area with no remediation whatsoever for its impacts.



In the photo to the left, we can see the utility of the global permafrost mapping tool, which could have identified areas where rock glaciers or other periglacial features might exist. The company should have carried out a glacier and periglacial inventory, and an impact assessment and run its roads through other areas.

Again, the damage was avoidable.

Unfortunately, in the past, mining companies operating in Argentina had no regard for the conservation of ice that was "in the way" of their activity. On the contrary, ice represented an impediment that complicated operations. It is also unfortunate that public officials, such as the current glacier inventory director for the province of San Juan, Mr. Silvio Peralta, Director of the INGEO (Geological Institute of San Juan Province), consistently denes that there is mining activity occurring in glacier areas—such as at the above example of Altar. [28] These statements only serve to discredit and generate mistrust of mining companies and of the public officials monitoring mining companies. When local populations and environmental organizations like CEDHA hear such statements they cannot but distrust public agencies. Examples such as Altar, El Pachón, Pascua Lama, Del Carmen and many others with clear and evident impacts of mining to glaciers and periglacial environments saturated in ice, are easily visible in Google *earth*. Such activity and situations are a direct violation of Argentina's National Glacier Protection Law. The denial of this reality by public officials is a complicit and illegal act.

[28] see: http://www.diariodecuyo.com.ar/home/new_noticia.php?noticia_id=439842

The reality is that periglacial environments were and are a headache for mining companies and that the Glacier Protection Law has arrived to further complicate things for mining companies working above certain altitudes in the Central Andes. If a mining company in the Central Andes is working above 3,000 meters (9,800ft), it is bound to find ice. When these companies begin operating in these frozen environments, machinery breaks, perforations are difficult, and the normal tasks of sampling or preparing a mining project for extraction is a more laborious and more dangerous task. Nonetheless, the companies are moving forward with their intentions, in many cases, without taking into account the risks and impacts caused to glacier resources or to periglacial environments. While in the past this was possible, today it is against law.

Barrick Gold for example, in their first environmental impact studies for the Pascua Lama project did not even list glaciers as a natural resource that could be affected by the project, and much less a natural resource that should be protected. Quite the contrary, Barrick Gold needed to clear away glaciers to get at gold. Glaciers were an impediment. Fortunately this attitude is changing. The Glacier Protection Law has changed up the circumstances and the due diligence and legal obligations for companies operating in high altitude environments, although, unfortunately, the practice of intervening and destroying periglacial areas has not ceased.

The geocryologist, Arturo Corte, founder of the IANIGLA and expert on permafrost and rock glaciers, says categorically:

> "During activities in permafrost areas, a reduction of the active layer [of rock glaciers] occurs, be it from the action of the wind, of traffic, of erosion, or the washing away by water, or by fusion; but what is worse is the folding influence of the vehicles and the effects of bulldozers that are used to level out roads, build parking areas, or introduce access points and service areas. For this reason it is essential to protect permafrost to the highest degree in areas of construction."(Corte 1993, p. 295)

For any industrial works introduced into a glacier or periglacial area, be it an access road or for drilling operations, when it is known that one is operating in a glacier or periglacial environment, one must take certain precautions to avoid impacts to these significant hydrological reserves. We must take all necessary measures to conserve and protect the basin regulatory functions of these cryological environments.

We can identify anthropogenic harm to a rock glacier or periglacial environment without needing to visit the site in question. Obviously, the specific extent of the damage will need a site visit to examine the detailed impact, but the impact itself is generally very easily visible by satellite. In this report, we have already seen images of mining projects such as Altar, El Pachón or Filo Colorado, etc. which show such impact, generally from mining roads. When the impact is to periglacial environments that do not have glaciers present, it is more difficult to determine impact using satellite images. This sort of impact (in areas with no visible glaciers or rock glaciers) usually requires a site visit.

Is it possible to see if a public work is affecting periglacial environments?

In some cases, yes. We can infer impacts by associating visible human-induced impacts to an area (such as a mining road) with probable presence of frozen grounds, as would be determined by the permafrost global mapping tool. If we see that there are active rock glaciers present, then we can presume that there will also likely be other ice-saturated frozen grounds in the vicinity at the same altitude as the rock glaciers. It's very easy to identify mining roads in satellite images, and so if these roads traverse areas that are likely to be frozen, we should be concerned at least to the point of requesting the necessary studies to determine risks and impacts. An example is Xstrata's Filo Colorado project, which cuts various rock glaciers. Both roads and rock glaciers are easily identifiable on satellite images, and therefore the correlation of mining activity to these resources is also easily established.

Where there is frozen ground *without rock glaciers present*, it is not as easy to determine. We can presume that the surrounding areas of an active rock glacier may be saturated in ice, but

we cannot be sure. We can however take on a precautionary position with respect to that supposition and command the necessary studies and inventories from the company and/or from the responsible state agencies. If the Zurich global permafrost model suggests the likely or possible presence of frozen grounds, we should definitely be requesting such studies.

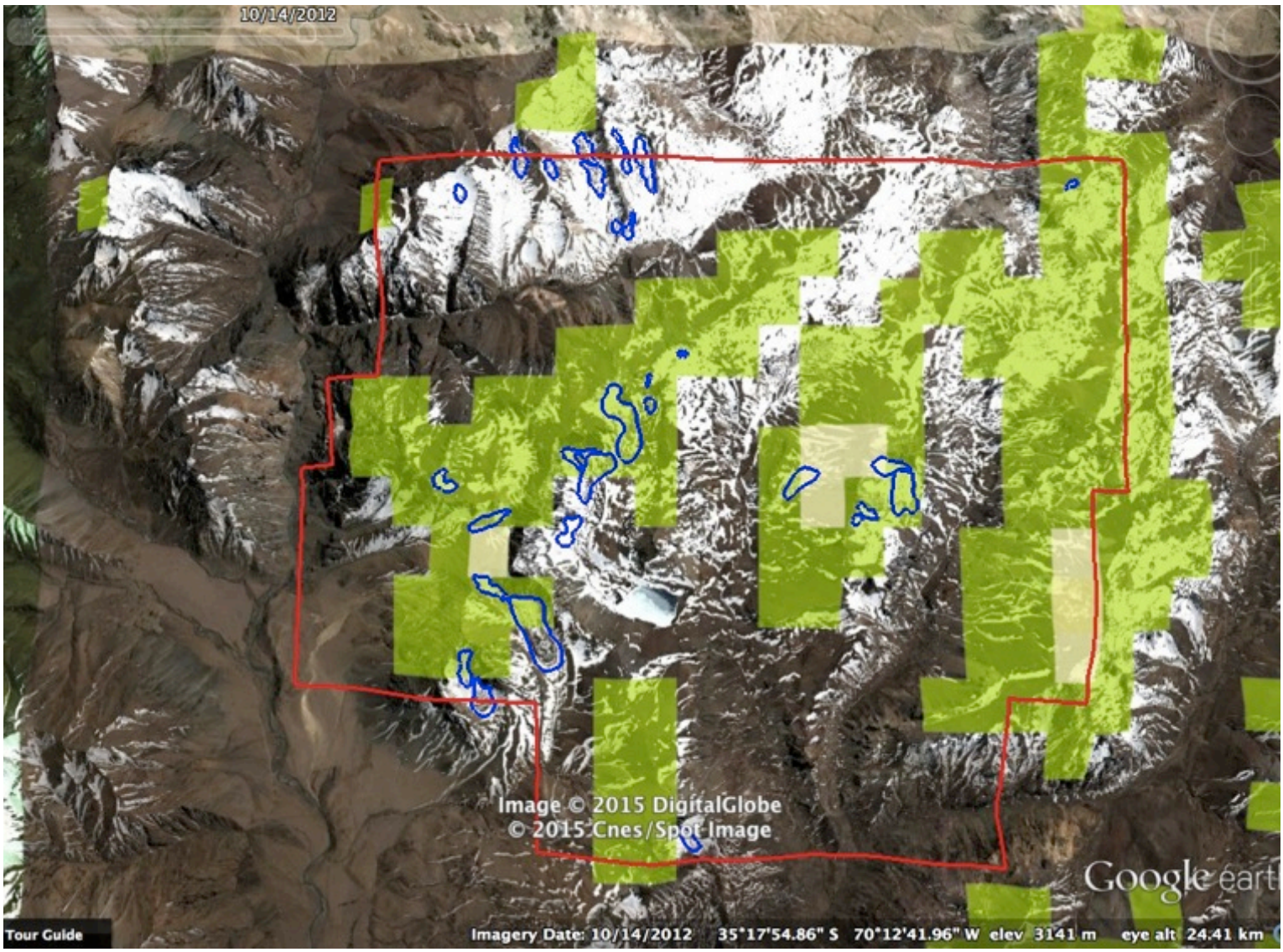
Many of these determinations about where to command studies, can be determined without a site visit. The official national glacier inventory will be an important reference point to establish areas that are of concern for glacier protection. Public officials should take note of the conclusions of this inventory in order to ensure that they call for all necessary detailed studies when industrial projects aim to develop in areas where glaciers and periglacial environments are present.

In the next image, taken at the El Pachón mining project in the province of San Juan (now the owner of the project is Glencore Xstrata), we can see how an exploration road has cut through an active rock glacier. This rock glacier and the mining impact to it can be seen on your smartphone at:

31 44 53 S, 70 27 15 W

Rock Glacier with mining road running through it, at El Pachón (Glencore Xstrata). San Juan Province: Photo location: 31 44 53 S, 70 27 15 W

There shouldn't be a single mining project in a periglacial environment, not even for exploratory activity, without the necessary inventory and glacier risks and impact studies carried out to ensure the protection of these vulnerable hydrological resources.



The Periglacial Environment, Glaciers and Rock Glaciers at Cerro Amarillo

The reader that has read this report up to this section, already has enough basic knowledge about rock glaciers and periglacial environments to understand the basic issues treated in this section.

After having reviewed available satellite images for the Cerro Amarillo mining concession, where glaciers and rock glaciers are visible (indicating that there is ice-saturated periglacial environment), and considering that the global permafrost mapping tool offered by the University of Zurich indicates some 50% of the concession is possibly frozen grounds, and considering that we have gathered testimonial evidence, including photographs taken in the area by CEDHA's team of collaborators, we can conclude *without a doubt*, that there are glaciers, rock glaciers and ice-saturated periglacial environments in the Cerro Amarillo mining project concession and that these hydrological resources are protected by the Argentine Glacier Protection Law.

We can debate about the specific characteristic of these glacier resources, if they are smaller or larger than we suggest, if they evidence active movement, or if they are in a healthy state or if they are vulnerable, but there is no doubt that the resources exist in the concession. We can also presume that due to the limited availability of satellite images of the area, we are likely to find more glaciers and/or rock glaciers in the concession.

Glacier Inventory at Cerro Amarillo

CEDHA's glacier inventory (see image above) registers at least 30 glacial bodies (amongst these, 13 uncovered glaciers representing 1.15 km^2 (.44 $miles^2$) and 17 rock glaciers representing 2.58km^2 (1 $mile^2$), for a total area of 3.73km^2 of ice (1.44 $miles^2$) in the Cerro Amarillo mining concession. Because of the snow cover in the satellite images, it is very likely that the number of glaciers that are actually in the concession is higher, since it is likely that with clearer images we will discover smaller glaciers in the concession area that are covered with seasonal snow in the images we have analyzed, making them invisible for analysis. The elevation range for these glaciers is as follows:

Rock Glaciers:	2,740 – 3,540 meters (9000 – 11,600 ft)
Uncovered Glaciers:	2,830 – 3,690 meters (9,300 – 12,100 ft)

Below we list each of these glaciers in our inventory, indicating the name assigned to the glacier by CEDHA, the type of glacier (uncovered vs. covered) and its elevation range. The reader can enter the glacier coordinate to see the glacier in Google *earth*, or on a smartphone. The reader can also download the *.kmz* file prepared by CEDHA to see the glaciers in Google *earth*. This file can be obtained at:

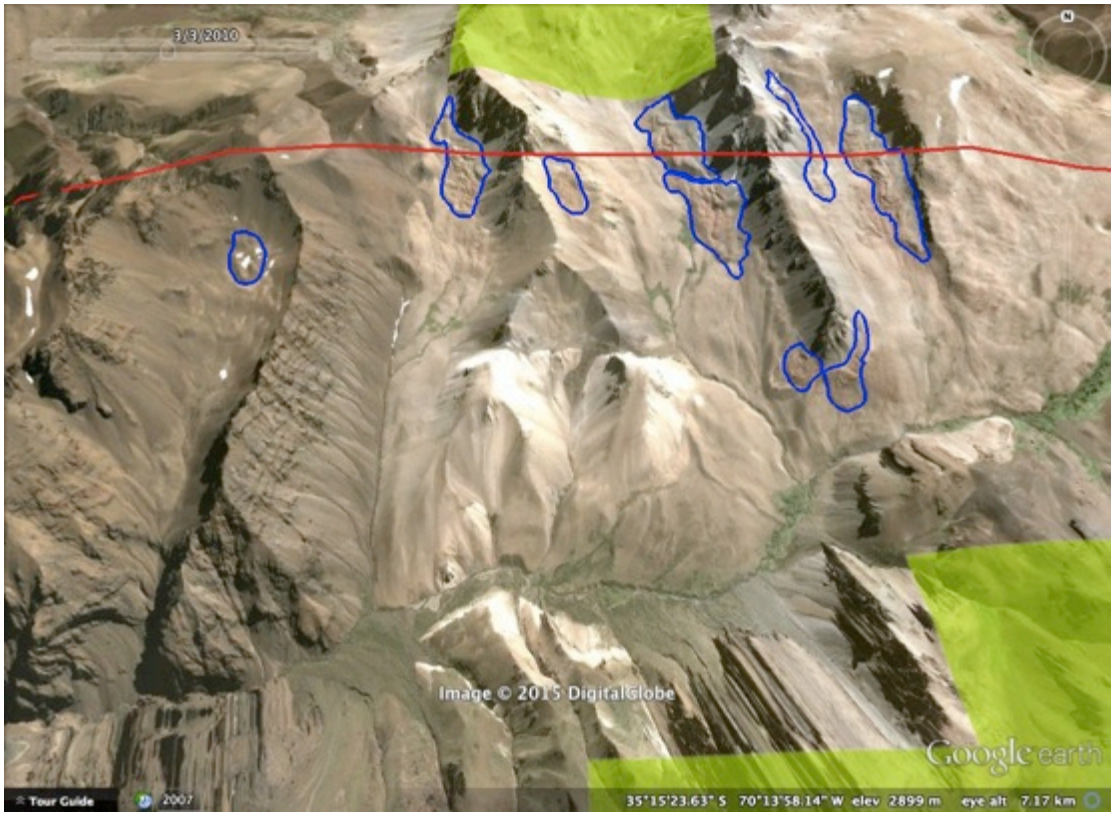
http://wp.cedha.net/wp-content/uploads/2015/02/Cerro-Amarillo-Project-Polygons.kmz_.zip

Name of the Glacier	Type	Coordinates	Elevation	Area (km^2)
Glacier R 3514-7012	rock	35 14 57.22 S, 70 12 40.35 W	2915-3100	.18
Glacier R 3514-7012 (b)	rock	35 14 38.71 S, 70 12 58.83 W	2960-3140	.07
Glacier R 3514-7013	rock	35 14 44.53 S, 70 13 24.36 W	2895-3000	.13
Glacier R 3514-7013 (b)	rock	35 14 55.46 S, 70 13 50.09 W	2970-3060	.05
Glacier R 3514-7014	rock	35 14 54.35 S, 70 14 11.36 W	2990-2990	.12
Glacier 3515-707	uncovered	35 15 7.54 S, 70 7 26.59 W	3205-3270	.02
Glacier R 3515-7012	rock	35 15 36.00 S, 70 12 52.31 W	2750-2900	.05
Glacier R 3515-7013	rock	35 15 3.92 S, 70 13 16.85 W	2855-2950	.15
Glacier R 3515-7013 (b)	rock	35 15 32.27 S, 70 13 2.14 W	2740-2910	.03
Glacier R 3515-7014	rock	35 15 13.19 S, 70 14 57.01 W	2940-3000	.05
Glacier 3517-707	uncovered	35 17 2.16 S, 70 7 16.69 W	3395-3510	.04
Glacier 3517-707 (b)	uncovered	35 17 50.33 S, 70 7 31.72 W	3455-3530	.06
Glacier 3517-709	uncovered	35 17 57.13 S, 70 9 48.25 W	3275-3615	.14
Glacier 3517-7011	uncovered	35 17 19.35 S, 70 11 33.73 W	2910-3095	.14
Glacier R 3517-7012	rock	35 17 30.59 S, 70 12 54.41 W	3125-3540	.49
Glacier R 3517-7012 (b)	rock	35 17 21.35 S, 70 12 35.63 W	3200-3290	.04
Glacier 3517-7013	uncovered	35 17 51.90 S, 70 13 31.99 W	3130-3480	.10
Glacier R 3518-709	rock	35 18 13.78 S, 70 9 31.58 W	3060-3280	.31
Glacier 3518-7010	uncovered	35 18 21.39 S, 70 10 3.78 W	3300-3690	.06
Glacier 3518-7010 (b)	uncovered	35 18 31.13 S, 70 10 8.05 W	3403-3610	.03
Glacier R 3518-7010	rock	35 18 7.11 S, 70 10 47.22 W	3090-3310	.16
Glacier 3518-7013	uncovered	35 18 38.67 S, 70 13 48.78 W	2960-3460	.12
Glacier 3518-7013 (b)	uncovered	35 18 33.95 S, 70 13 29.09 W	2915-3090	.12
Glacier R 3518-7013	rock	35 18 4.06 S, 70 13 12.28 W	2990-3170	.32
Glacier R 3518-7014	rock	35 18 34.06 S, 70 14 37.23 W	3240-3510	.13
Glacier 3518-7015	uncovered	35 18 8.08 S, 70 15 7.34 W	3360-3450	.09
Glacier 3519-7014	uncovered	35 19 8.64 S, 70 14 30.97 W	3240-3590	.11
Glacier 3520-7014	uncovered	35 20 0.69 S, 70 14 47.54 W	2970-3425	.12
Glacier R 3520-7014 (b)	rock	35 20 19.63 S, 70 14 37.69 W	2830-3060	.20
Glacier R 3521-7012	rock	35 21 39.14 S, 70 12 6.07 W	2960-3220	.10

TOTAL Glacier Cover:	**3.73km^2**
- Uncovered (13):	**1.15km^2**
- Rock (17):	**2.58km^2**

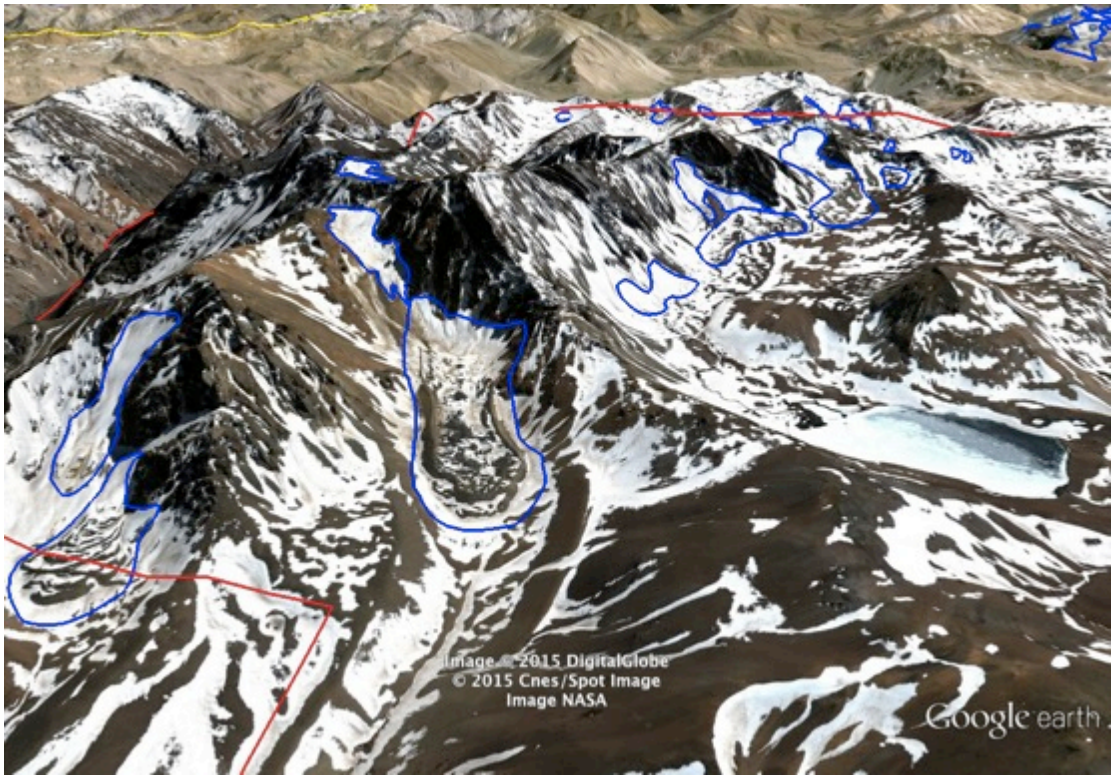
North West area of the concession (35°15'38.27" S 70°13'51.19" W)

This area has at least 9 rock glaciers located in the very extreme North West portion of the concession. There is a possibility of finding other ice-saturated grounds in the area in addition to these rock glaciers. It's an area of the concession, where according to Meryllion Resources, there are no projected mining activities. We do not know whether there have been past invasive exploratory activities in this area.



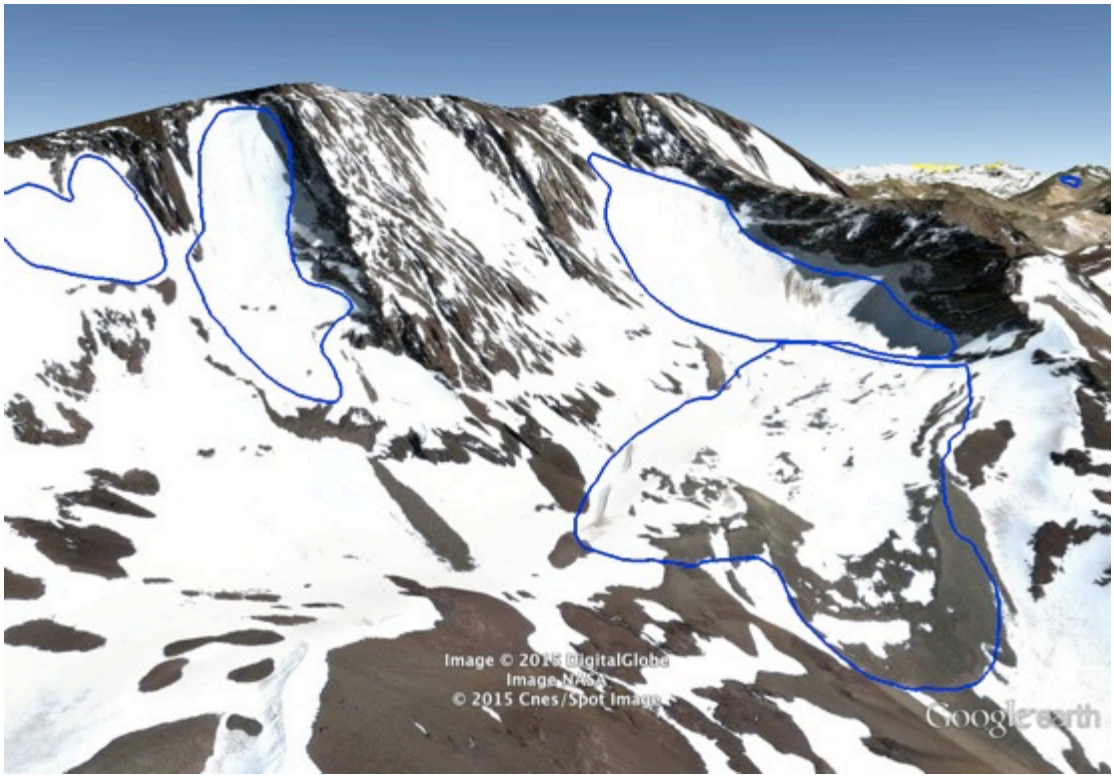
South West area of the concession (35°18'27.82" S 70°13'14.42" W)

This area at the South West corner of the concession has some 14 glaciers, amongst these uncovered glaciers and rock glaciers. It is an area rich in hydrological resources, evidenced by the presence of lagoons formed by the melt from snow and periglacial environments. It is the area of main mineral interest for the company, and where it has concentrated much of its mineralization testing.



Central area of the concession (35°18'20.93" S 70°10'06.68" W)

In this area we identify 5 glaciers of which there are uncovered glaciers as well as rock glaciers. The significant seasonal snow cover in the images does not allow us to determine if there are additional small glaciers in the area.

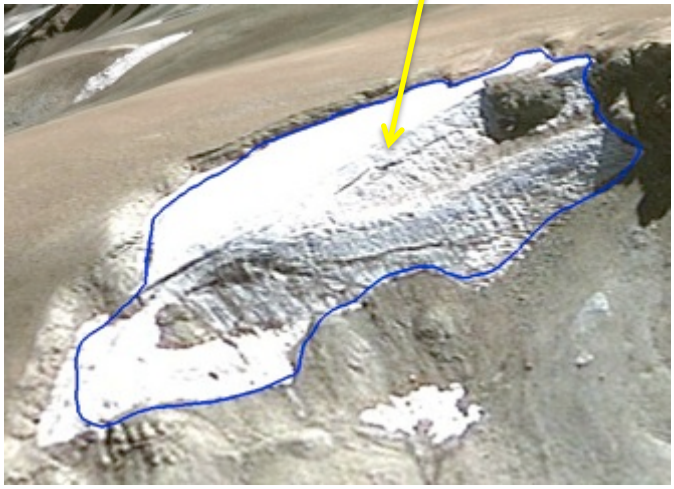


Southern area of the concession (35°21'38.81" S 70°12'22.11" W)

In this area we identify a glacier system that may be a mixed system between a debris-covered glacier and a rock glacier. There may be debris-covered glaciers in this area (these are different from rock glaciers, generally holding *more* ice than a rock glacier).

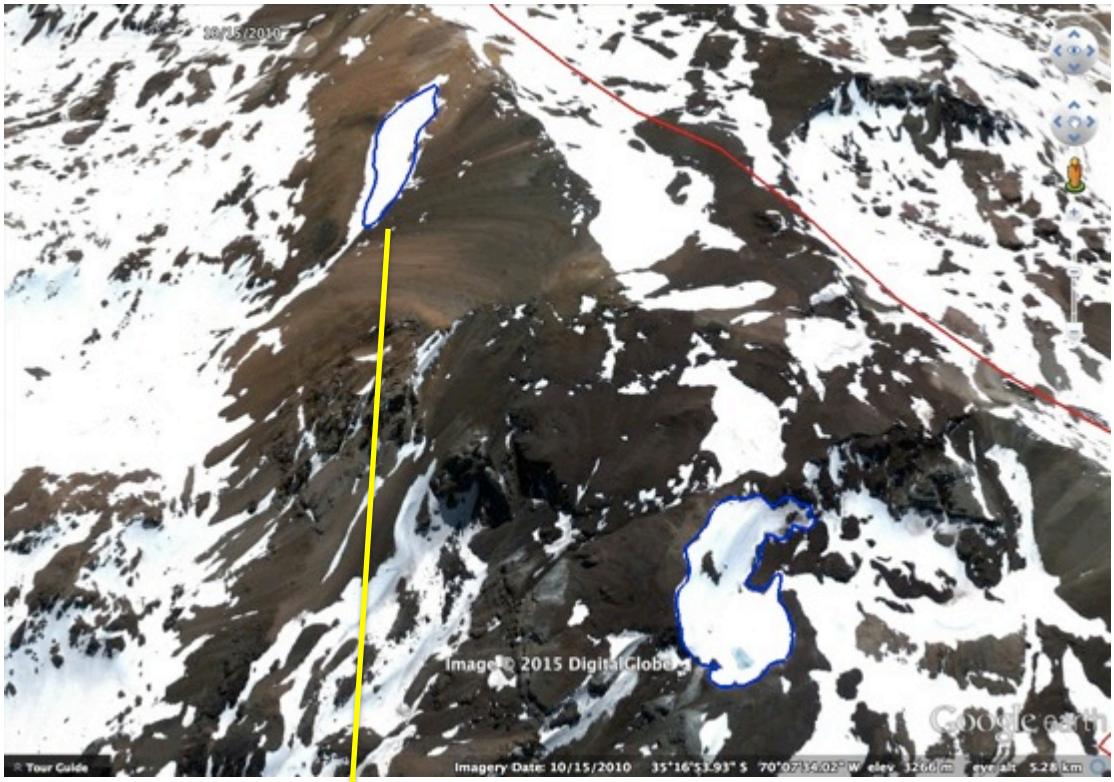
North East area of the concession (35°15'33.26" S 70°07'38.36" W)

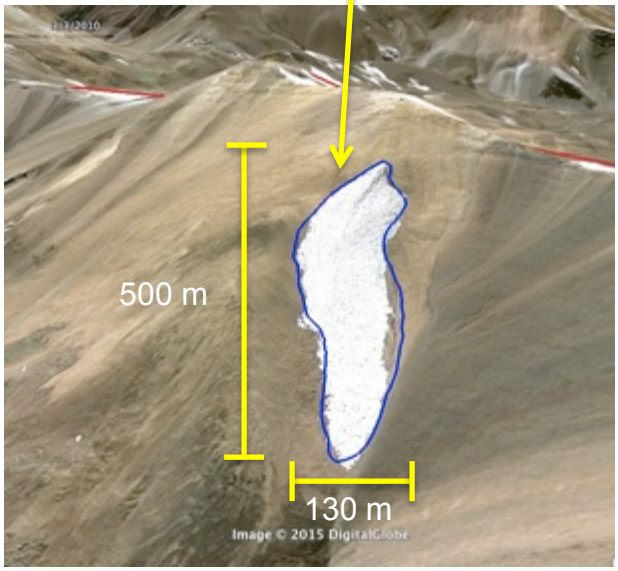
In this area we identify a small uncovered glacier, and the possibility of permanently frozen grounds, although the seasonal snow cover and the few satellite images available probably hide other small perennial ice bodies that would qualify as ice protected by the National Glacier Protection Law. New images obtained from the IANIGLA (the Argentine National Glacier Institute) suggest that there are indeed other glaciers in this area.



Western area of the concession (35°17'28.24" S 70°07'20.55" W)

In this area we've identified uncovered glaciers, and the possibility of additional glaciers, which we cannot determine because of the poor quality of the satellite images available. The images have too much seasonal snow cover.





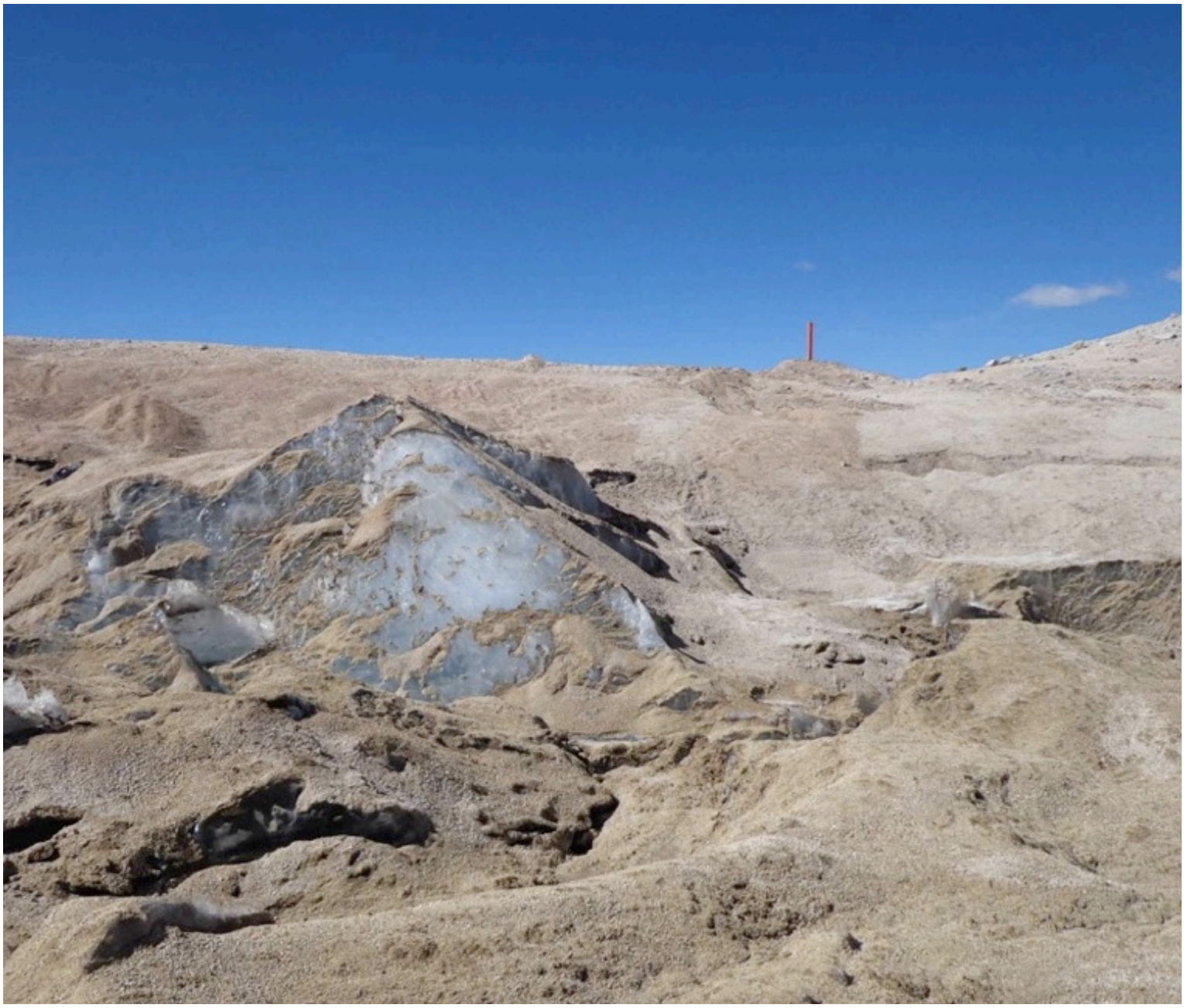
It is evident that the Cerro Amarillo mining concession has all types of cryogenic resources, including glaciers, rock glaciers and ice-saturated periglacial environments. This is shown in CEDHA's report. But what do public agencies say about this concession and the possible glacier resources it contains?

Since the official national glacier inventory is not yet published, these bodies of ice that are protected by law, with a mining project about to undergo activity in the area, are in a complete state of vulnerability. For this reason it is paramount to complete the official glacier inventory,

so as to establish the physical boundaries where mining activity can take place, and where it cannot.

Below we see what can happen to a glacier left to the will of an irresponsible mining company, in this case, it's the Toro 1 Glacier at the future pit site of Barrick Gold's Pascua Lama project. This once "uncovered" white glacier, very similar to some of the glaciers we see at Cerro Amarillo, is now completely covered by dust and debris from Barrick's blasting in the pre-stripping phase of the project. Barrick Gold has not even commenced extractive operations at Pascua Lama and this glacier has already been severely, possibly mortally, impacted. We should note that Barrick Gold has not been able to advance with Pascua Lama precisely because the Chilean authorities halted the project due to its glacier and periglacial environment impacts. Incredibly, the same project, at the same site, but on Argentine soil, has gotten a "thumbs up" from San Juan's mining and environmental authorities, suggesting the company does not impact glaciers. The authorities go even further by unbelievably saying that there is no mining activity in glacier areas on provincial soil. This denial by Argentina's public agencies is lamentable, and only serves to discredit all of their work and statements about the impacts of the mining sector. They simply cannot be trusted to protect the environmental resources that are affected by mining activity.

The Toro 1 Glacier, similar to glaciers at Cerro Amarillo (for example Glacier 3517-707), was completely covered by dust and rock debris from blasts at the Pascua Lama mining project by Barrick Gold.



Will the IANIGLA inventory the periglacial environment at Cerro Amarillo?

Partially. We should be clear that the IANIGLA (Argentina's National Glacier Institute) will review satellite images for the presence of uncovered glaciers and of some of the geoforms of the periglacial environment, such as rock glaciers. They will do an exercise similar to the one CEDHA has done for this report. However, the IANIGLA will not necessarily do a site visit, and even if they do, their responsibilities at the site visit are merely a sample site check of their work. Counter to what many some believe, they will not do a full periglacial inventory of the concession area. They will not do such an inventory because it would be simply impossible to do a full periglacial inventory and measurement of all of the periglacial areas of the country. They would not have enough time in their entire lives to carry out such an inventory. Such analysis is timely and costly, which is why this responsibility is given to the actors that are voluntarily conducting activities (such as mining operations) in the area.

The IANIGLA will identify and inventory "some" elements of the periglacial environment, and its work will amount basically to desk research. They will reveal for example, the presence of rock glaciers, which are "one" of the most notorious elements of the periglacial environment and that are visible in satellite images. This can easily be done in Google *earth* as we have done. But as is very clear in the IANIGLA's plan of implementation[29] of the national glacier inventory, "the periglacial environment has many geoforms with ice in their interior". However, the IANIGLA will only focus on rock glaciers for the inventory, and will ignore other very relevant ice-saturated cryogenic resources, such as ice-saturated creeping grounds, which are also very significant hydrological resources and which are protected by law.

Further, according to the inventory, only glaciers with an aerial surface area of more than $0.01km^2$ or 100 x 100 meters (328ft x 328ft) will be inventoried (that's about the size of a football field). This limit is set for a practical reason, so that smaller bodies, which can be in great numbers, do not have to be listed in what would be a very tedious task. We should not confuse this technical limit stipulation to suggest that small perennial ice patches, or what some call "glacierets" do not in their entirety, amount to very significant amounts of ice. Quite the contrary, these ice patches can collectively be even more significant in terms of water contribution than larger glaciers. We must also stress that even though the IANIGLA may not register these smaller glaciers or ice patches in their inventory, they are still very much protected by the Argentine National Glacier Law, which makes no distinction by size in terms of glacier protection.

In the same way, we must be clear about the fact that the IANIGLA will not reveal the totality of the periglacial environment in any area of the country. The capacity of the staff simply cannot complete such an inventory in their lifetime. There may be periglacial areas with no visible rock glaciers that will not be included in the IANIGLA glacier inventory. These areas may very well have active ice-saturated content protected by law, but it will not show up in the official list of glaciers or glacier inventory.

For this reason, the global permafrost model of the University of Zurich is extremely useful to map frozen grounds and to be able to take a precautionary approach with the mapping that results from the model. The model helps us demarcate lands where we have at least a suspicion of finding ice-saturated frozen grounds. With the model we can ensure that any industrial activity to take place in areas determined by the model to potentially have frozen grounds, be closely tested for rock glaciers or other ice-saturated grounds.

[29] Inventario Nacional de Glaciares y Ambiente Periglacial: Fundamentos y Cronograma de Ejecución; see: http://www.ambiente.gov.ar/archivos/web/SUBpolitica/file/CronogramaInventarioGlaciaresIANIGLA.pdf

Has Meryllion Resources already conducted their own inventory and study of the frozen grounds in the Cerro Amarillo mining concession?

In all likelihood, yes.

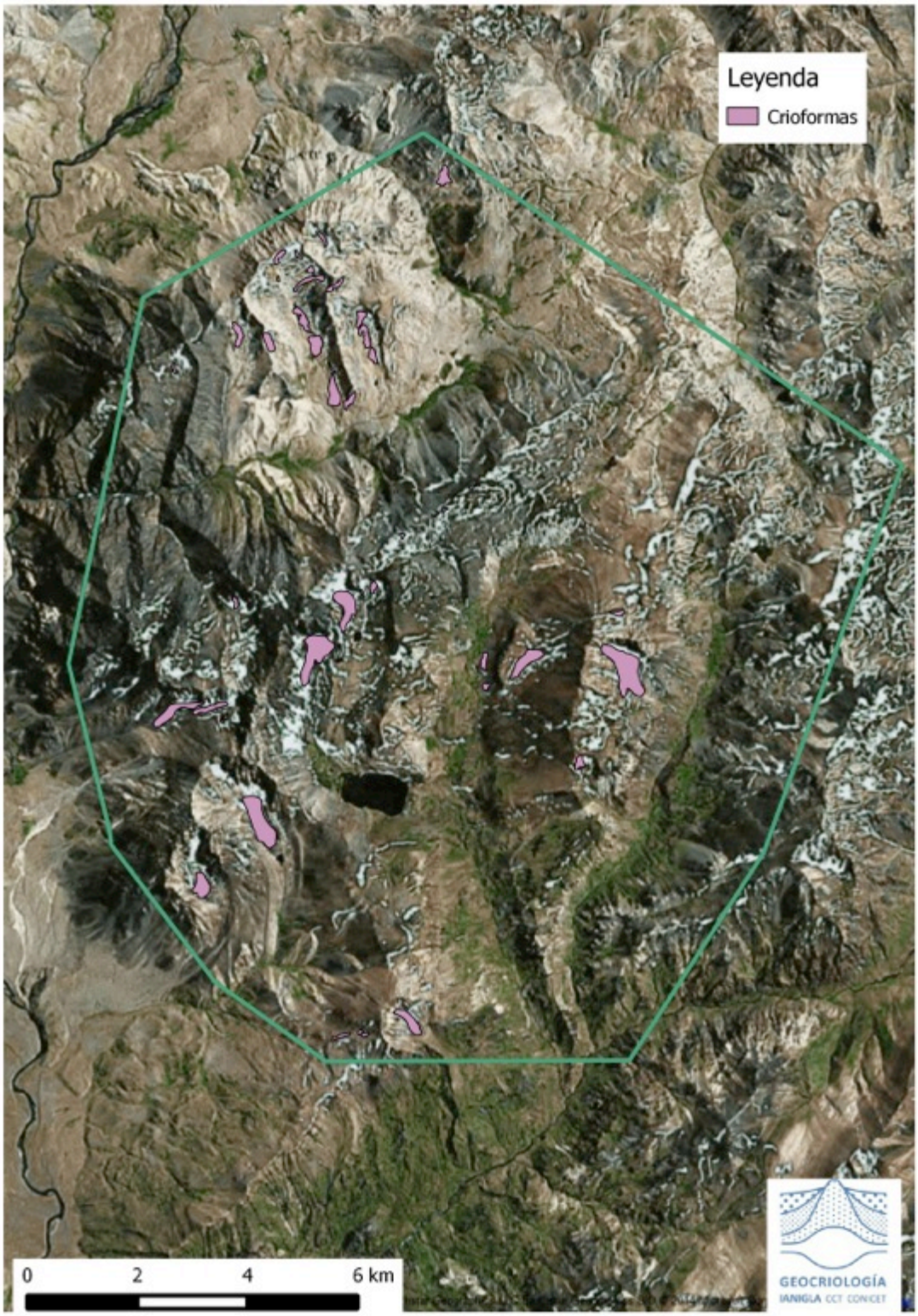
Meryllion Resources has its own glacier inventory of the concession area. They should publish it. However, this work has not been released to the general public. In conversations that the author of this report had with staff of Meryllion Resources (*virtually* in Canada and *personally* in Buenos Aires), the company has alluded to an in-house glacier inventory.

The glacier inventory and the analysis of frozen grounds is important for the company and for any activity the company plans in the concession, not only because it is seeking mineral resources and needs to know the surface composition of the concession, but because ice-saturated frozen grounds are extremely vulnerable and unstable. If they place weight, such as machinery or sterile rock on such grounds, there is risk that the instability might cause tragic slides. This was the case of Barrick's Veladero mining project in San Juan Province[30], when the company chose, against recommendations to the contrary, to site one of its sterile rock piles on periglacial environment. The result was a sudden collapse of the rock pile, and a slide of a rock pile the size of a small town, down a mountain slope. This type of accident, potentially deadly for mine workers or anyone stationed below the pile, can be avoided by a good study and proper glacier and periglacial due diligence.

[30] see: http://wp.cedha.net/wp-content/uploads/2011/10/Special-Report-waste-pile-collapse-ENGLISH.pdf

Preliminary Glacier Inventory by the IANIGLA

In the run-up to the publishing of this report, we were able to obtain a partial glacier inventory by the IANIGLA of the area of Cerro Amarillo. In this image we see a glacier inventory in evolution by the IANIGLA that confirms the presence of ice at Cerro Amarillo. The IANIGLA mapping of glaciers does not differ substantially from CEDHA's own inventory.



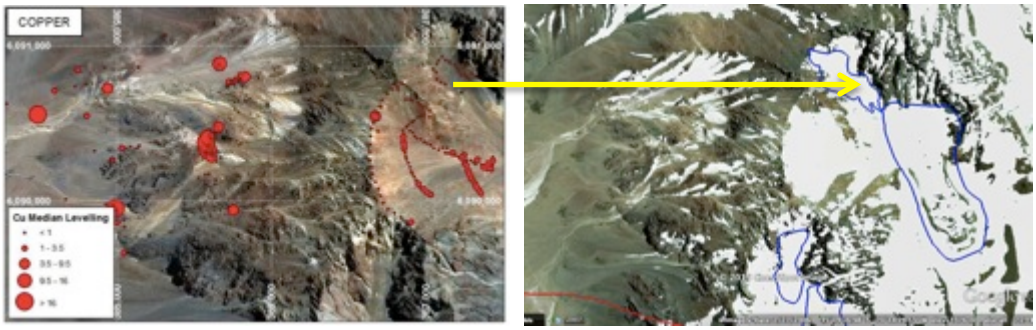
Overlap of Mining Activity with Glacier and/or Periglacial Areas

In terms of risks and impacts of mining activity to glacier and periglacial resources, the principal question we should ask ourselves is if there have been or will be risks or impacts to glaciers, to rock glaciers or to other ice-saturated elements of the periglacial environment by past, present or future mining activity at Cerro Amarillo.

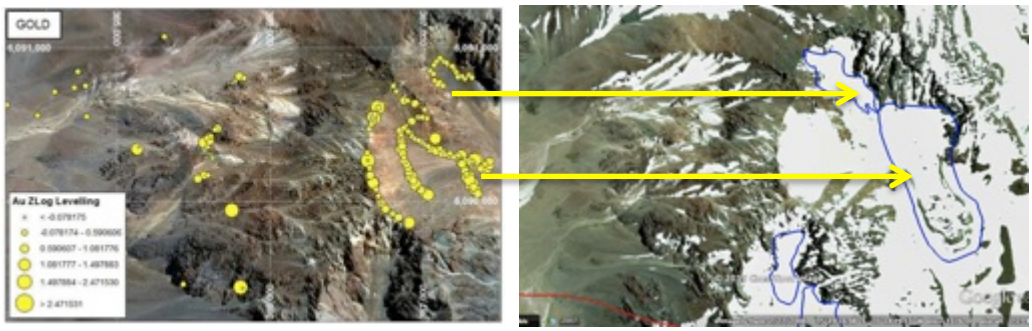
To answer this question, we must first define if past activity or programmed activity at Cerro Amarillo occurred or will occur in areas where there are glaciers, rock glaciers and/or periglacial environment, or where such activity could affect glaciosystems that are conducive to the formation and sustainability of glaciers.

According to the information we have obtained regarding recent and proposed activity for the future at Cerro Amarillo, combined with the satellite images we have analyzed and which are presented in this report, we can say that effectively there are coincidences between past mining activity, and with present or planned future mining activity with areas that have glaciers, rock glaciers or other periglacial features.

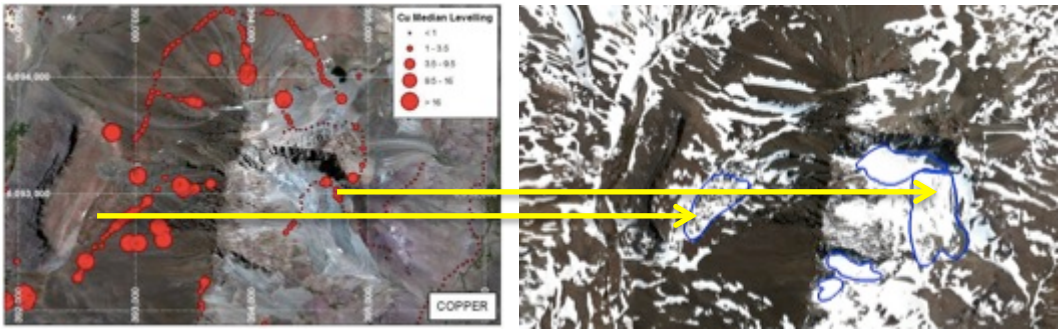
The following images offer information to sustain these arguments. They are the mapping of minerals presented by the company in their reports. The fact that the company knows that these minerals are present in these areas implies that they have been to the areas and taken samples at the sites (these samples have supposedly been non-invasive—without drilling). The information presented by the company also implies that they could be areas for future drilling.



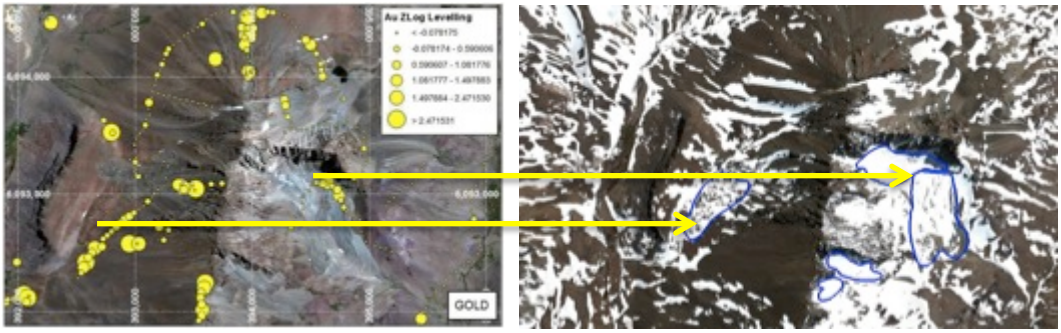
Copper mapping (red dots) and the presence of glaciers/rock glaciers in the area of La Blanca (glaciers are blue polygons). Source: Meryllion Resources



Gold mapping (yellow dots) and the presence of glaciers/rock glaciers in the area of La Blanca (glaciers are blue polygons). Source: Meryllion Resources

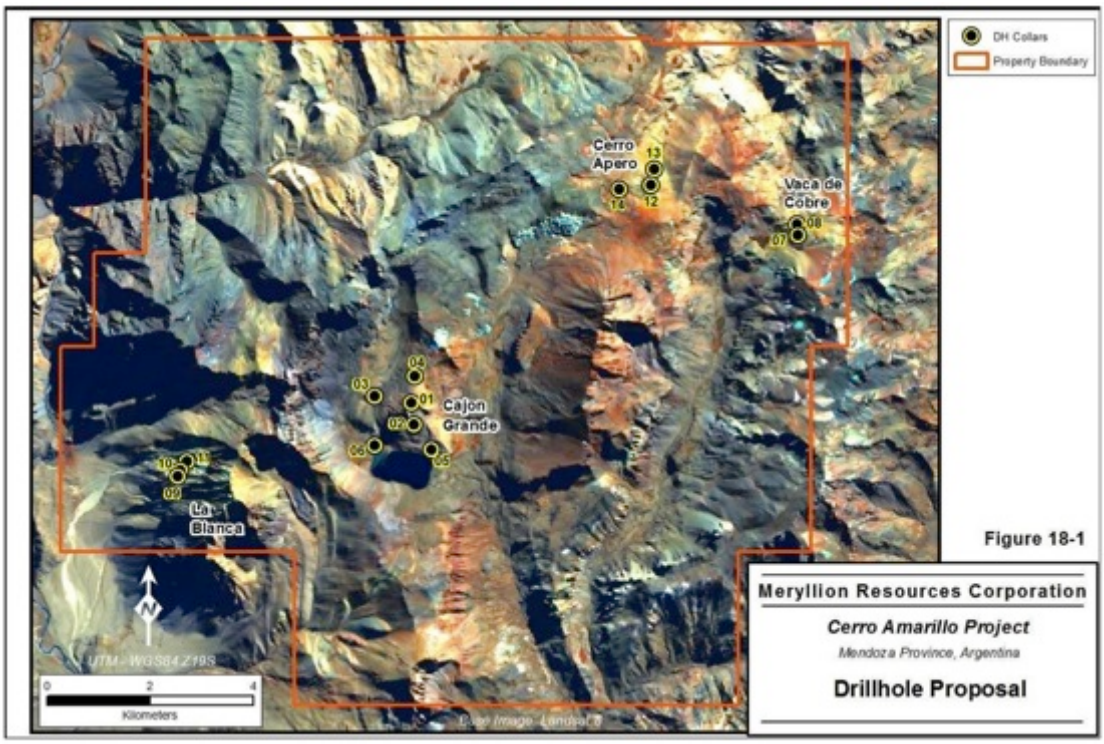


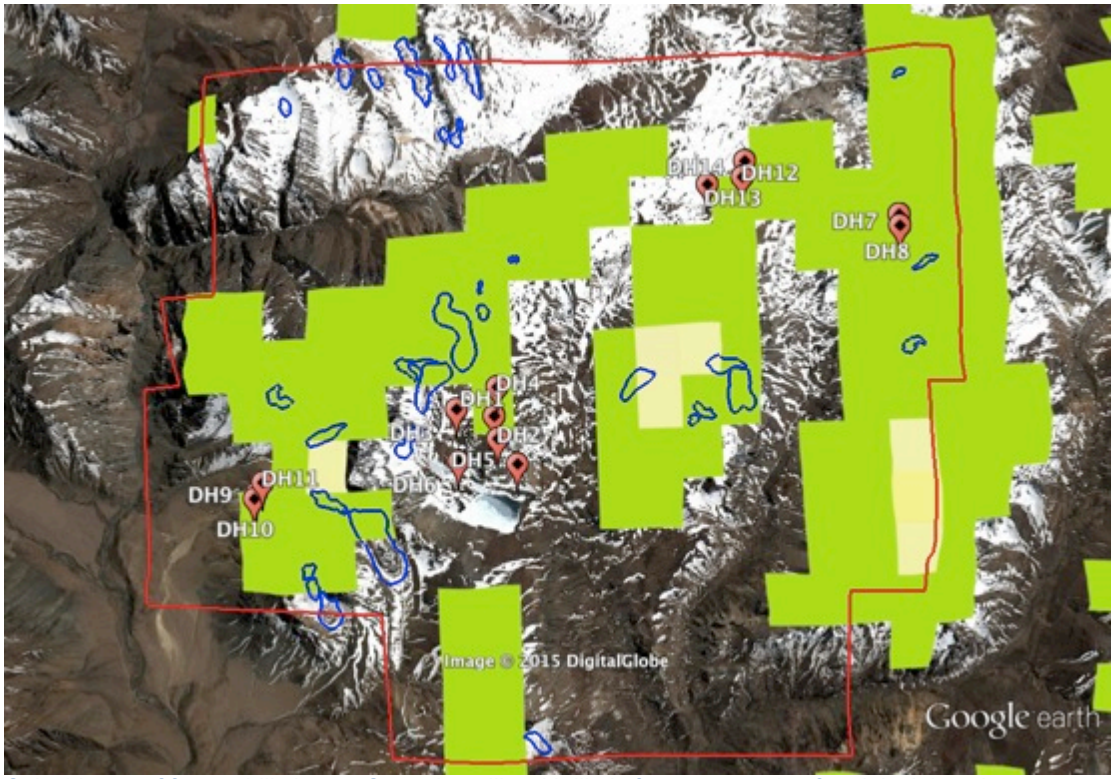
Copper mapping (red dots) and the presence of glaciers/rock glaciers in the area of Cerro Chorro and coincidence with glaciers (glaciers are blue polygons). Source: Meryllion Resources



Gold mapping (yellow dots) and the presence of glaciers/rock glaciers in the area of Cerro Chorro (glaciers are blue polygons). Source: Meryllion Resources

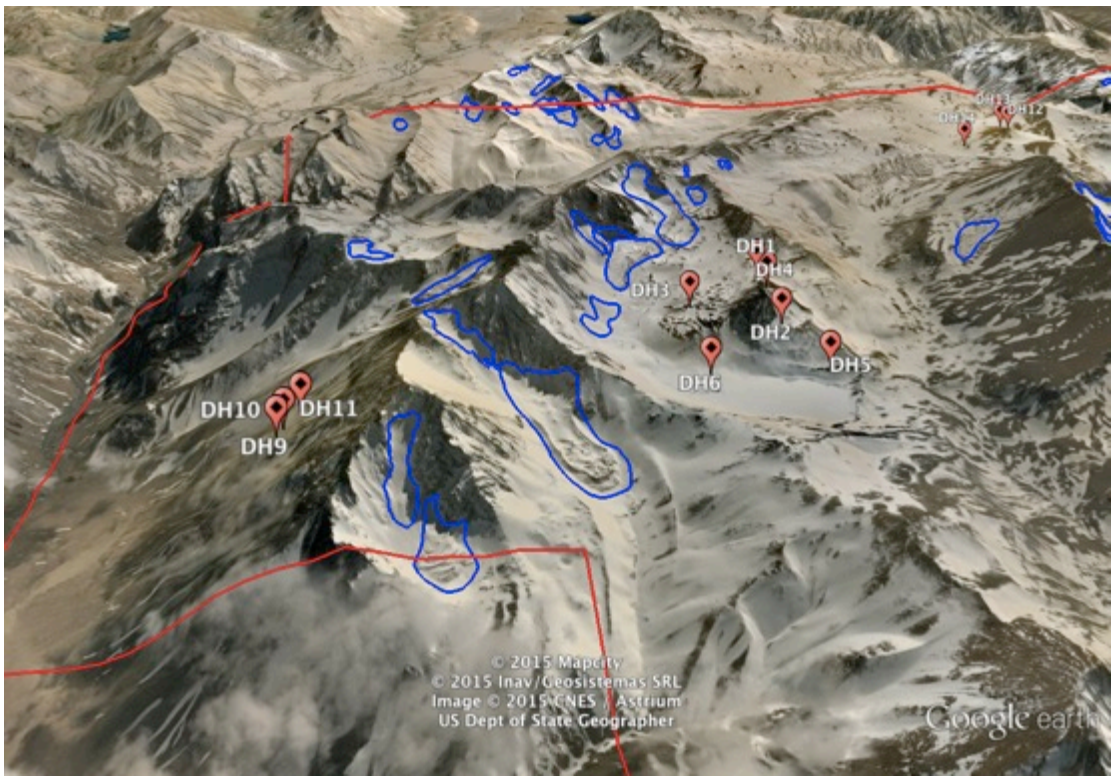
We can also find coincidences between the areas marked for future drilling and areas with potential ice-saturated frozen grounds. When we compare the mapping of future drill holes (DH), DH4, DH7, DH8, DH9, DH10, DH11, DH12, DH13 (first image) to the presence of potentially frozen grounds (second image), we see a clear coincidence. While drill hole DH1, DH2, DH3, and DH4 appear to be outside or at the margins of permanently frozen areas, their proximity merits further studies.

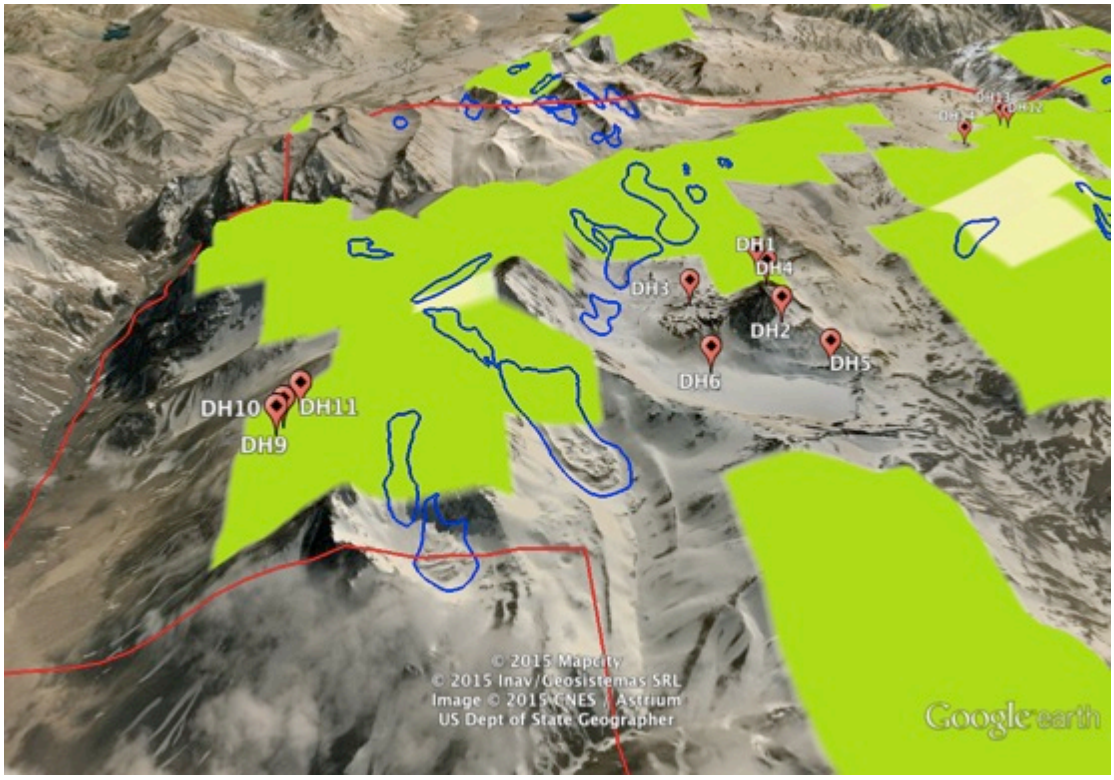




Coincidence of future drill sites at Cerro Amarillo with likely frozen grounds of periglacial environments.

In the next image, we can appreciate with greater detail, the significant proximity of future drill sites with glaciers and rock glaciers. In the second image we see the same sites with the permafrost global mapping tool superimposed. In the second image we that the drill holes most at risk are DH1, DH9, DH10, and DH11.





There is no doubt that there is sufficient and important coincidence between frozen grounds and mining activity at Cero Amarillo, enough so to merit further studies, and especially a risk and impact study to evaluate if mining activity would damage these resources.

Potential Impacts to Glaciers and Periglacial Areas by Cerro Amarillo

What does the past, present or future mining activity at Cerro Amarillo imply for glacier and periglacial resources in the concession area?

Recall that some of the mining activity that can impact glaciers, rock glaciers and periglacial environments are (this is not an exhaustive list):

- Introduction of roads
- Excavations
- Drilling
- Blasting
- Traffic
- Other contamination in the area

We must point out that the stages of mining work (prospecting, exploration, preparation, extraction, closure) have diverse and different impacts, and that generally (but not always) these risks and impacts increase with the evolution of the project.

First off, we must note that according to the reports by the company, as per the technical study published by Meryllion Resources in July of 2014, there has only been light exploration at Cerro Amarillo, carried out by horseback, on foot, and by helicopter. The images available on Google *earth*, do not show any type of mining access road in the area, or drilling platforms, which would coincide with the claims of the company. However, we should stress that our latest image of the concession dates to September of 2013. We cannot know if more invasive activity has occurred since this date.

Considering that Meryllion Resources has carried out exploration activities after this date, we cannot know for certain if there has been removal of soil, drilling or other invasive activity at the concession. Based on the claims of the company, and the fact they have requested permits to the provincial authorities for drilling (which have been turned down), we suppose that there have not been such activity that would negatively affect a glacier, a rock glacier or periglacial environments in the concession area.

At the same time, we must be aware of the risks that would be implied if new stages of exploration are to move forward, such as drilling, moving of soil, introduction of roads, prior to the necessary inventories and glacier and periglacial impact studies.

Given that the company has already announced its intention to drill and the specific drill sites where it wants to drill, and that we have already identified the location of glaciers, rock glaciers and periglacial environments, there is enough information present to warrant an in-depth study of eventual risks and impacts of these activities to these resources.

We also point to the importance of taking into account the future glacier inventory produced by the IANIGLA, since the information therein contained will permit us to more precisely map glaciers within the concession area. Utilizing such information, we can call for the necessary impact studies to gauge mining activity risks to glaciers, rock glaciers and periglacial environments and establish the necessary no-go zones for all mining activity in the area as well as zones where mining activity should be closely monitored and controlled.

Of special concern would be:

- Any drilling on ice-saturated frozen grounds;
- Any movement of soil on ice-saturated frozen grounds;
- Any introduction of roads on ice-saturated periglacial environment;
- Any blasts upwind of uncovered glaciers;
- Any introduction of roads upwind of uncovered glaciers;

What impacts could be caused by future activities at Cerro Amarillo, for example, the desire to drill 5,000 meters (16,400ft) to take new samples?

Here we can definitely speak of potential impacts to glaciers, rock glaciers or periglacial environments, and thus, we must take precautions if we are to allow such activity to move forward.

Considering that we can affirm:

- There are frozen grounds in the concession area;
- That there are uncovered glaciers (even if they are small) in the concession area;
- That there are active rock glaciers and possibly also inactive rock glaciers in the concession area;
- That there are possibly (non-glacier) ice-saturated frozen grounds;

there are various types of possible impacts from intensifying exploration activity at Cerro Amarillo.

1) That glaciers, rock glaciers and ice-saturated grounds be impacted by the removal of surface cover; this can occur due to the introduction of access roads, introduction of drilling platforms, or by drilling;
2) That there is impact to glaciers, rock glaciers and ice-saturated grounds due to the lubricants used in drilling activity;
3) That vehicular transit impacts glaciers due to dust and fuel emissions which can soil glaciers;

How can we avoid these impacts?

First of all, by not authorizing any permits for any additional mining activity until the appropriate inventories and impact studies are completed and that these studies assure that glaciers, rock glaciers, and other hydrological resources of the periglacial environments (such as creeping grounds, etc.) are not at risk.

Conclusions

It is evident that we are before an emblematic case that has recently surfaced in Argentina, in which cryogenic resources (glaciers, rock glaciers and periglacial environments) are at risk because of the advancement of mining activity in the Central Andes.

It is important to place each element of our discussion in context and thoroughly understand the risks that are implied in the authorization of the advancement of mining activity in very delicate hydrological systems of these high mountain environments. We are not being extremists or taking a dogmatic position against or in favor of mining, but rather, we are simply calling on public officials to take the necessary steps to avoid damage to very sensitive and very critical natural resources. These resources are not minor resources, they are at the very top of the hydrological water chain. We must also ensure that all actors are in compliance with existing laws.

The Argentine National Glacier Protection Law is very clear over the importance of cryogenic resources, and establishes the categorical prohibition of activities that might damage this resource. What we need to gauge, hence, is if the activity proposed by the Cerro Amarillo mining project will negatively impact glaciers, rock glaciers or periglacial areas. If it does, it is illegal. If it doesn't then it could legally move forward (at least as concerns glacier protection).

In this determination we must first determine where is this protected resource. More specifically, where are the glaciers, rock glaciers and periglacial areas in the project's concession. The inventory currently underway by the IANIGLA will officially answer part of that question, that is "where are the glaciers". It will also respond the question of "where are the rock glaciers". But it will not respond the question, "where is the ice-saturated periglacial environment", which is also protected by law. The IANIGLA will also not necessarily tell us where smaller glaciers, less than 0.01km^2 also protected by law, are located.

For this reason, it is important to proceed with caution, assuring that the identification of glacier resources is complete, and that all of the cryogenic resources at risk due to mining activity will be identified. The IANIGLA inventory will not do this! And, if mining activity will place any of these resources at risk. If any of Cerro Amarillo's mining activity would impact any of these legally protected resources, Cerro Amarillo would not be able to move forward because it would be illegal.

We hence call on public officials, provincial and national authorities specialized in environmental and mining issues, particularly the IANIGLA, the Environment Secretariat and the Mining Secretariat, to ensure that the proper studies are carried out to shed light on the risks to glaciers, rock glaciers and periglacial environments at Cerro Amarillo.

This report by the Center for Human Rights and Environment (CEDHA), offers very clear and certifiable information, showing that there are cryogenic resources (glacier resources) inside the Cerro Amarillo mining concession. We show without a doubt that there are glaciers, rock glaciers and periglacial environments in the Cerro Amarillo mining concession. All of these resources are protected by law. We don't see or know of any special environmental impact study to assess risks to these glacier and periglacial resources by Meryillion Resources or by any another company or agency. It is time for the State authorities to take the necessary steps to ensure the protection of this very vulnerable and strategic resource.

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About the Author

In Rodeo, Cuesta del Viento, San Juan Province, with the Central Andes in the Background

Jorge Daniel Taillant (Daniel) has more than 15 years of experience in issues related to sustainable development. He has worked for numerous agencies and organizations, amongst these, non-profit organizations, multilateral institutions (World Bank, UN, EU, OAS, etc.) and as advisor to governments.

Daniel's professional career initiates focusing on public policy and local development issues. He turns later to environmental policy and human rights in a business context. He has lived in North America, Asia, Europe and several counties in Latin America. He returned to Argentina in 1999 with his wife to found The Centro de Derechos Humanos y Ambiente (CEDHA), in Córdoba Argentina. CEDHA focuses on the defense of victims of environmental degradation and promoting a more harmonious relationship between the environmental and people. Some of CEDHA's focus areas are: climate change, right to water, corporate accountability, participation and access to information, forests and mining. Over the last several years, he's focused personally on the impacts of mining to glacier and periglacial environments.

In 2007, CEDHA wins Sierra Club's prestigious Earth Care Award grounded on CEDHA's innovative approach to pushing for greater accountability, human rights and environmental protection in the corporate world, in the well known pulp mill sector case involving the companies, Botnia and Ence. A year later, his spouse and Co-Founder of CEDHA, and former Secretary of Environment of Argentina (2006-2008), Romina Picolotti won the acclaimed "the Sophie Prize" for CEDHA's innovative contributions to linking human rights and the environment.

Daniel has dedicated the last 5 years to studying the impacts of mining on glaciers, particularly in the high Andes Mountains. He is also pushing for greater transparency, access to information and participation in the extractive sector. This work has looked carefully at the impacts of mining operations on glaciers and periglacial environments, including the launching of the "Democratizing Glaciers Initiative", which aims to construct more civic engagement around environmental protection through glacier protection. He is developing scholastic materials on glacier protection and vulnerability and is helping educate communities about the vulnerability of glaciers and the many important contributions they make to local ecosystems.

En 2012, CEDHA organized a conference at Rio + 20 called Glaciers and Sustainability in the Anthropocene.

In the context of his work on mining and glaciers, CEDHA is conducting a national glacier inventory, focusing on glaciers in mining regions. CEDHA already has registered over 3,000 glaciers in provinces such as San Juan, Catamarca, La Rioja, Jujuy, Salta, Mendoza and Tucumán. This is a direct contribution to the implementation of the National Glacier Protection Law.

Daniel is the author of numerous publications on the impacts of mining on glaciers.