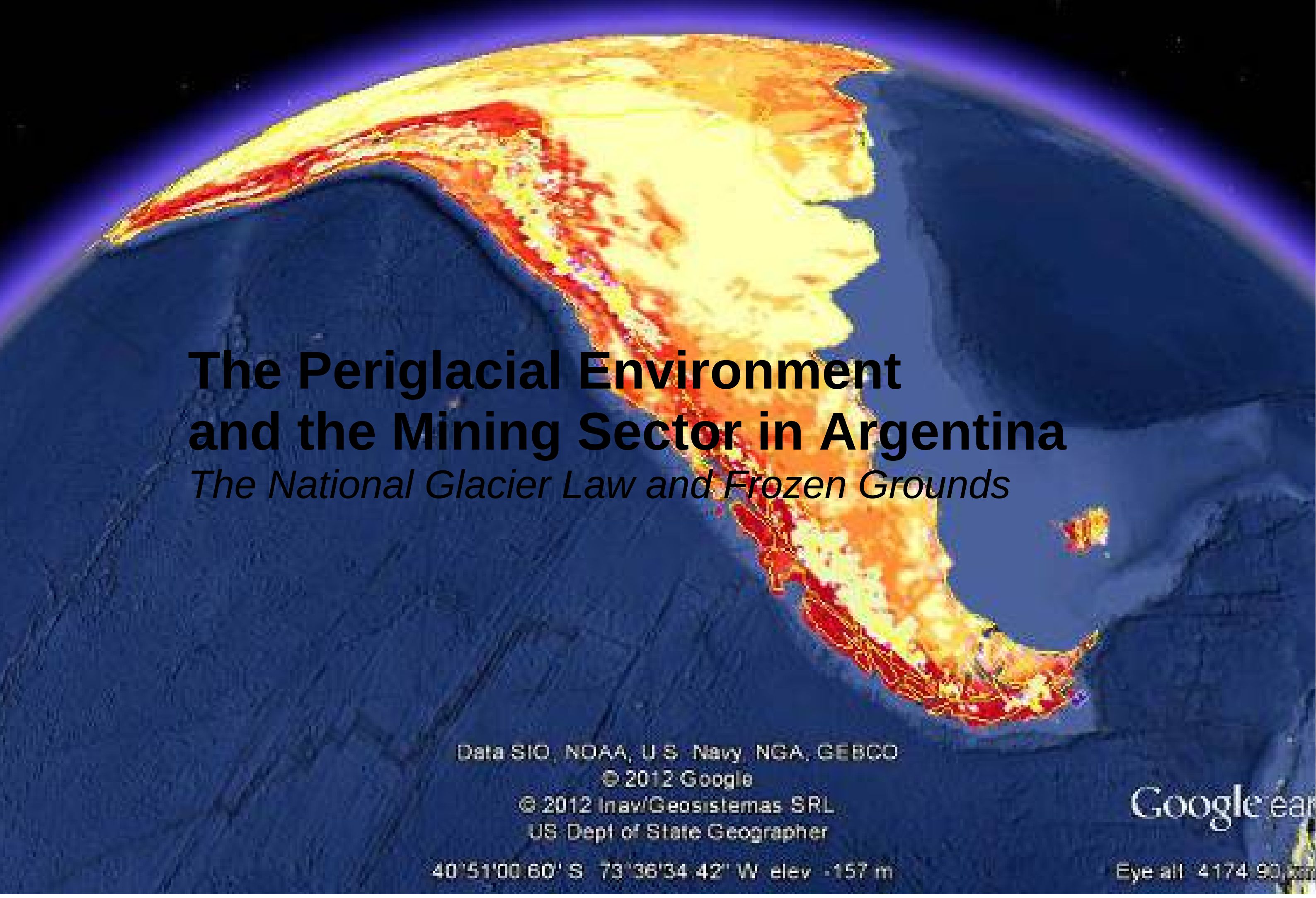
The Periglacial Environment and the Mining Sector in Argentina

The National Glacier Law and Frozen Grounds



Permafrost Areas of the Periglacial Environment in Argentine Territory. Source: *Google earth* & University of Zurich

This version is a translation of the original Spanish version; all translation of academic references are UNOFFICIAL. In case of technical doubts of terminology used, the Spanish version is the principal text.

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The reader of this report is invited to download the permafrost global map produced by the University of Zurich, a file with extension .KMZ that is viewable in *Google earth*. With this file opened in *Google earth*, whatever place on the globe that is viewed is automatically superimposed with a mapping of permafrost areas. In regards to the topic presented in this report, this permafrost mapping coincides to a large extent, with the periglacial environment protected by the “Minimum Standards Regime for the Preservation of Glaciers and Periglacial Environments”, more commonly known as Argentina’s “National Glacier Law”.

To download the permafrost map, click on the following link:
http://www.geo.uzh.ch/microsite/cryodata/pf_global/GlobalPermafrostZonationIndexMap.kmz

You can obtain more information on the work of the University of Zurich at:
http://www.geo.uzh.ch/microsite/cryodata/pf_global/

You can obtain more information on CEDHA and its work to project glaciers at:
http://wp.cedha.net/?page_id=4196

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Context

This publication aims to identify the elements and essential characteristics necessary to consider the relevance of protecting water resources contained in periglacial environments as well as the eventual impact that extractive industry activity and other works of magnitude might have on these resources in Argentina.

The ultimate objective of this work is to disseminate information to a non-expert public, about periglacial environments, and to offer the basic elements from a public policy perspective so that personas that are not necessarily focused on the issue of glaciers, or more specifically on "geocryology" (the combination of geological studies and ice studies), can take the necessary precautions to protect this important hydrological resource. Periglacial environments, different from glaciers, are also hydrological resources and also contribute significantly to regulate water basins, and for this reason they are also protected by the National Glacier Law.

Executive Summary

The periglacial environment, despite limited studies focused on this resource in the region, is one of the most important sources of water once winter snowfall melt has completed. The hydrological contribution of periglacial environments is greater than that of glaciers, and larger than that of rock glaciers (rock glaciers are but *one* element within the periglacial environment). Climate change accelerates glacier melt, which means in turn that periglacial environments will increase their relevance over time as water provider with respect to the provision from uncovered glaciers. That is, as glacier cover diminishes, periglacial environments will contribute a greater amount of water in percentage terms as compared to uncovered glaciers.

There are extensive periglacial environments, saturated with ice, containing permanently and temporarily frozen grounds, which cyclically freeze and unfreeze, and that act as water basin regulators and/or as natural water reservoirs These are located in the Central Andes and other mountain ranges in provinces such as San Juan, Mendoza, Catamarca, La Rioja, Tucumán, Salta and Jujuy. Despite the fact that the Argentine National Glacier Law establishes the protection of the periglacial environment and the requirement that the government conduct an inventory of the periglacial environment, at present there is no official mapping of these environments for Argentine territory. The IANIGLA (Argentina's glacier institute) is currently carrying out an inventory of "cryoforms" or "geoforms", in the periglacial environment, but we do not yet know when it will carry out an inventory of the hydrological resources present in extensive areas containing frozen grounds (permafrost), independently of the cyroforms that might exist in these environments. The frozen grounds of the periglacial environment are also key elements because they function as water basin regulators. The periglacial environment, not including glaciers, could be more significant as water basin regulators than the glaciers themselves.

The federal Glacier and Periglacial Environment Protection Law establishes the obligation to carry out priority glacier and periglacial environment inventories, where mining operations or other large works are currently underway that might affect these resources, for their value as water reservoirs and as basin regulators. There is no evidence at present that these priority inventories are taking place. According to the established chronogram for the official inventory, currently underway by the IANIGLA;

> The inventory analysis in priority zones should take place within 180 days and as such, are not comprised under the general chronogram presented for the remaining areas of the country. For the moment, no priority zones have been identified in the mountains and as such, the magnitude, the staff needed, the financing and other particularities of the exercise are unknown and will likely be defined in the near future.[1] *(this is an unofficial translation)*

We do not know why "no priority zones have been identified in the mountains", but they should have been identified within 180 days of the entry into force of the law, which implies end April 2011. Further,

[1] In: Inventario Nacional de Glaciares y Ambiente Periglacial: Fundamentos y Cronograma de Ejecución. IANIGLA. P.48.

these zones are easily identifiable via *Google earth*. In fact, our organization (the Center for Human Rights and Environment) has published numerous reports showing mining activity in glacier areas, at projects such as Filo Colorado (Xstrata Copper), Agua Rica (Yamana/Xstrata), Los Azules (McEwen Mining), El Altar (Peregrine/Stillwater), Del Carmen (Malbex), Pascua Lama (Barrick), El Pachón (Xstrata Copper), Amos Andres (Rio Tinto), Rincones de Araya (Amansa), Amiches and Sancarron (Argentina Mining), Potrerillos (Golden Arrow), José Maria (NGX Resources), Las Flechas and Vicuña (NGX Resources), among many others. For more information see: http://wp.cedha.net/?page_id=6258&lang=en).

We suppose that the failure of carrying out the priority inventories is due to the failure by the provinces where mining operations are being carried to inform the IANIGLA and/or the National Environment Secretariat (which is the agency entrusted with implementing the Glacier Protection Law) where the current mining projects in their territory are located.

While there may yet exist an official registrar for periglacial environments, there are ways of obtaining this information, by inference and by direct observation. Technology already exists that is available to anyone, with minimal capacity training and an Internet connection, to identify periglacial environment in the high mountains. These techniques, while only a preliminary approximation in the confirmation of periglacial environments, are extremely useful and provide very indicative and very reliable information on the presence of periglacial environments. The University of Zurich has recently published a free and public global mapping of permafrost (frozen grounds), visible through *Google earth*. Our experience after having carried out numerous inventories of glacier and periglacial geoforms (such as rock glaciers) verifies that the mapping by the University of Zurich is highly precise to prognosticate periglacial environments.

There are also other studies that have been carried out by renown professionals in the geology field, as is the case of the consulting firm URS (which carried out the geomorphological mapping of the El Pachón project (Xstrata Copper) in San Juan Argentina, which maps rock glaciers and reveals some 20% permafrost areas, which largely corresponds to the measurements estimated for the same region by the tool developed by the University of Zurich.

The permafrost mapping by the University of Zurich includes all of Argentina's territory, and as such, this work is an excellent base, conducted under undisputable scientific rigor, to at least establish at a preliminary level, where Argentina's periglacial environments are located. With this information we can provide a fundamental basis to conduct further studies, with more detail and depth with a view to identify strategic grounds and take the necessary steps for their protection. By cross-referencing this information with the mapping of mining activity, we can rapidly define zones where the priority glacier and periglacial environment inventories should take place.

We can easily corroborate in this permafrost mapping of Argentina, that many mining ventures and other large works (such as roads) or mining access roads, are in periglacial environment zones. These mining projects and infrastructure works, in these periglacial environment zones, are taking place without the necessary studies as mandates by federal law 26.639 (Minimum Standards Regime for the Preservation of Glaciers and Periglacial Environments). The interested provinces do not yet have priority glacier and periglacial environment inventories, and if any private entities have carried out such inventories, as we know many extractive companies have, this information is not publicly available, and further, it is systematically denied to those that have interests in the information. The areas where these mining ventures are taking place, is readily visible via satellite images that are publicly available through programs such as *Google earth*.

In the annex of this report we provide a list of at least 53 different cases in provinces such as Jujuy, Salta, Catamarca, La Rioja, San Juan, and Mendoza, where there are conflicts between mining projects and/or roads, or with other commercial projects, with periglacial environments.

In each of these case, according to the National Glacier Law, activity that could impact these water resources should cease until the proper studies are carried out to determine the presence of glaciers, debris-covered glaciers, rock glaciers and periglacial environments, in order to determine if past, present or future activity, might impact this resource. If such impact is confirmed, the activity should be moved, modified, or ceased.

We call on provincial and national public authorities, and on mining companies that are responsable for these activities to comply with the National Glacier Law, and that they suspend all type of activity in periglacial environment areas until we can assure that they are not impacting glaciers, rock glaciers, and/or periglacial environments.

Periglacial environment impacted by exploration and drilling at the El Altar project (Stillwater) in San Juan, Argentina.

Background

Until very recently, approximately at the end of 2008, very few people in the world had ever heard of the term "periglacial environment". Practically nobody (save for glaciologists, and select geographers and geologists, knew of the "periglacial environment"). In Argentina, practically no one had ever heard of the term.

In Argentina, this is changing and now many people speak of the *periglacial environment* and the need to protect this important water resource. The discussion around this term began from the moment Argentina adopted in 2008 a Glacier Protection Law, which included the *periglacial environment* as a publicly protected good. The inclusion of the periglacial environment in the National Glacier Law occurred thanks to the IANIGLA, which added this focus of the law to an earlier draft of the law which did not include it. The law protects the periglacial environment for its function in providing water and also because it is a significant water reservoir in high mountain areas.

The very name of federal law 26.639 includes the term *periglacial environment:* "Minimum Standards Regime for the Preservation of Glaciers and **Periglacial Environments**".(emphasis added)

Article 1 of the Glacier Law states (unofficial translation):

> The following law establishes the minimum standards for the protection of glaciers **and the periglacial environment** with the objective of protecting them as strategic freshwater reserves for human consumption; for agriculture and as sources for watershed recharge; for the protection of biodiversity; as a source of scientific information and as a tourist attraction. (emphasis added)

Periglacial environments benefit form the same protection as glaciers, and this is undoubtedly due to the fact that they are as important as public good as glaciers. In fact, as we will see below, periglacial environments are more important that glaciers themselves in terms of water basin regulation.

Glacier protection became the center of a profound debate over the necessity to protect critical water resource in the form of ice in high mountain altitudes, as today it is at risk due to natural climate tendencies, due to anthropogenic climate change tendencies and due to certain local industrial activity, including extractive industry activity which is specifically addressed by the National Glacier Law. There are also impacts due to other anthropogenic works such as the introduction of and maintenance to roads.

When the National Glacier Law is unanimously passed by the National Argentine Congress in the year 2008, neither the Congressional representatives nor the public in general knew much about glaciers resources in the country, and less even, or practically nothing at all, about the periglacial environment as a water resource. We didn't know of the role these resources play in the ecosystems which they nourish. We knew little about the water regulation role that these ice resources have on the ecosystem, although we all probably imagined that glaciers generally were important water reservoirs. Surely anyone could imagine that the enormous Patagonian glaciers, some of which are more than 15kms long, could contain a lot of water, but we did not realize that even a small glacier the size of a football field in the province of San Juan or Tucumán, might be able to supply an entire family with a generation's worth of water.

Surely we did not realize that in Argentina and in the Andes more generally, there were so many glaciers. Most Argentines knew of only one glacier, the *Perito Moreno,* which is a very emblematic glacier in Patagonia because it receives national and international tourists year round. Maybe a few others knew of the Upsala, Viedma, or Spegazzini glaciers, which are each just as impressive as the Perito Moreno. But practically no one knew that there were *thousands* of glaciers in Argentina, in fact that there might be tens of thousands of them, and that many of these are actually below the surface of the earth, the so called, "debris covered glaciers" or "rock glaciers".

Even fewer imagined that there were entire mountains, frozen, saturated in ice, and that because it is frozen, the entire mountain can conserve water in a solid state and when it unfreezes, the mountain releases water just as do glaciers, regulating the flow of water to lands below. We could not imagine, only a few years ago, the water regulation role that these mountains could play. We did not know of the permafrost zones of the *periglacial environment,* and particularly the discontinuous permafrost zones that cyclically freeze and unfreeze, and that these zones could be even more significant than glaciers themselves in terms of water provision. All of this was unknown.

Surely many had heard of the term "permafrost", and they might have imagined that it had something to do with ice, snow, and the earth. "Permafrost" comes from the term "perma" (or permanent) and frost (frozen), and simply means "permanently frozen". Permafrost (frozen ground) is *one* element of the periglacial environment, but it is not synonymous with the term, although many utilize the terms interchangeably. What is certain is that until very recently, the term "periglacial environment" was a term that was reserved for a few scientists dedicated the study of a branch of glaciology, of geography, and geology, and of *cryo-geology*.

Today, Argentine society is learning about these terms and their meaning with respect to their natural resource value and we are taking the necessary steps to assure their protection.

The majority of Congressional representatives that voted in favor of the National Glacier and Periglacial Environment Law, *which we should stress is the first of its kind anywhere*, thought that they were voting for a law to protect glaciers. They imagined that they were voting to protect large glaciers like the Perito Moreno in Patagonia. The majority had no idea that in provinces such as San Juan, Tucuman, Catamarca, La Rioja, Salta or Jujuy, all known to be hot and arid regions, there could be glaciers and even less so that there were hundreds, even thousands of glaciers. And they certainly did not know that in addition to glaciers, that extensive sections of the grounds of the provinces could be permanently frozen and contain significant amounts of water in the form of ice, in reserve for when nature and communities that live beneath them need the resource. This is a fact that still today escapes the majority of people.

The objective of this report is precisely to start to revert this situation.

The *Algarrobo* Rock Glacier in periglacial environment areas of the Aconquija range, border between Catamarca and Tucumán

*There are extensive frozen grounds (or permafrost) with important amounts of water in reserve, and for this reason tose that drafted the National Glacier Protection Law, wisely decided to include frozen grounds and more specifically, **the periglacial environment**, as a legally protected public good. This report attempts to explain in a simple and understandable manner, what this resource is, what it is like, where it is, why it's important, and which are the risks to the periglacial environment due to mining and other significant activities of large scale.*

What is the Periglacial Environment?

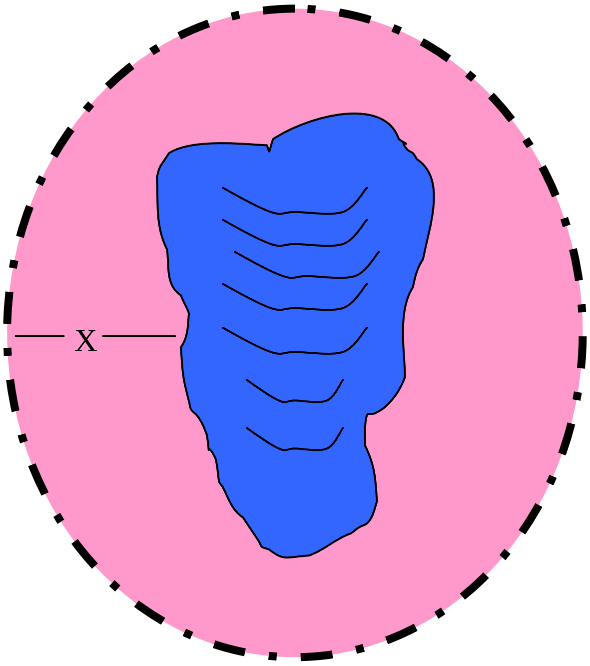
Let's begin with the opposite question, as logic doesn't serve our purpose in this case, since despite what most might presume, there can be a periglacial environment *without* a glacier!

So then, what **is not** the Periglacial Environment?

When most people hear the term *periglacial environment* for the first time, the imagine a simple definition, largely because of the simplicity of the term itself. They think logically as would an environmentalist, but not as a "glaciologist" or much less as a cryogeologist—a person that studies the periglacial environment—would think.

One imagines a definition because of the etymological roots of the term. We image a peripheral space (from the word "peri") around the glacier, and we imagine that this physical space around the glacier has some relevance to the ice of the glacier. We might also imagine a sort of buffer zone around the glacier, necessary to protect the glacier.

We might imagine a system as the one depicted below, where the glacier is the blue mass in the center of the circle and in which the "periglacial environment" would be a zone around the glacial mass at some distance "x" from the glacier. The dotted line in the image below would more or less demarcate this *presumptive* "peri" glacial zone, which we have colored in a pink tone. .



This "buffer zone" would likely be at some fixed distance from the glacier body, 15, 150, o 500 feet from the glacier? We might even consider further distances for a buffer environment, maybe 5, 10 or 15 kms from the glacier? We've seen references to such distances in select documentation. These would be safe distances from the glacier so as to ensure that activities nearby do not harm the ice. We presume by intuition that this buffer zone around the glacier should have some ecosystemic value to the glacier. We imagine that every glacier has its "periglacial environment" and that every "periglacial environment" in this framework corresponds to an existing glacier. We imagine that the periglacial environment is a sensitivity zone for the glacier, and that whatever occurs inside this zone could impact the glacier, and that for this reason, the new National Glacier Law, establishes the need to protect the periglacial environment.

This reasoning is so logical that the Argentine institution that knows most about glaciers, the IANIGLA, begins its definition of the periglacial environment precisely by refuting these presumptions!

The periglacial environment is NOT the area around a glacier!

The IANIGLA anticipates this erroneous supposition from the public and on its website on periglacial environments states (unofficial translation):

> We can say that at first glance, if we think in epistemologically, the term "periglacial" means "around or near a glacier or glacial processes". Peri = around, near, and glacial = adjective related to the presence of glaciers or glacial action. While without a doubt, this is a valid analysis, as occurs with many scientific terms, if we only accept this interpretation, we would be erring. [2]

If we go back in time a bit, one of the most renown experts on the issue of land and ice (a cryogeologist), Arturo Corte, already in the 1980s suggested that the term had to do with:

[2] see: http://www.glaciares.org.ar/paginas/index/periglacial

> Geophysical geological processes of marginal freezing and unfreezing of glaciers. *But* [that] we know that areas that are far from, or have no connection to glaciers, have intense geocryological activity …. [and] … that the dryer a cold region, the more active is its cryogeological activity. The example is in the Dry Central Andes of San Juan and Mendoza, where there is an altitudinal layer of more than 1,600 meters of ice stored in debris (Permafrost, from 3,200 meters to over 4,800 meters).

Corte also warned that there could be periglacial environments (geocryological regions) with no glaciers!

And hence, *the "periglacial environment"* ***is not*** *the area around a glacier.* It's important that we stress this point for many reasons. In the first place, because the definition of a *periglacial environment,* has strictly nothing to do with a glacier, and as such, it would be a mistake from a environmental public policy perspective, or in a policy designed to project glaciers, or in the case of a corporate policy designed to reduce impacts on glaciers, to limit the policy to protect those areas where we see glaciers, or even to limit it to those areas where we see debris-covered glaciers or rock glaciers.

We cannot conclude that because we don't see any uncovered glaciers present in an area, that there is no periglacial environment. We can say the same of rock glaciers. We cannot conclude that because we do not see rock glaciers present in a given area, that there in no periglacial environment. This would be a shortsighted and incorrect presumption. We emphasize this because we have already heard numerous public officials working in the mining sector, or focused on glacier policy, make public statements of this nature, in provinces such as San Juan and La Rioja.

We shall see in the following pages that the physical space of which we are speaking when we address the periglacial environment is much broader than simply the space around uncovered or debris covered glaciers. It is important to remember that we also have to look for periglacial environments *where we may not see any glaciers all of any type*. Furthermore, this clarification is important because the physical space that *is* around a glacier, but that is not part of the glacier, *is not* considered by the definition of the glacier nor in the definition of the periglacial environment. As such, this physical space around the glacier is not protected by law when the law refers to the *periglacial environment*. If this space is invaded or impacted, in geophysical or natural terms, could affect the glacier or the periglacial environment. Hence, it is important to protect this space "around the glacier" if in the end we want to protect the glacier. In this regards, and strictly speaking if we protect the "periglacial environment' we are not necessarily protecting the space around the glacier, which in turn is important for glacier conservation.

Regarding this *space around a glacier*, there is no scientific term to distinguish this physical space that surrounds the glacier. This is an important semantic gap because it is important for glacier conservation. For this reason, we've introduced a term that can help us from a public policy and environmental policy perspective, and in terms of extractive industry policy, which helps us address glacier protection more generally. We call this space, the glaciosystem. This report will not enter into detail on the glaciosystem, but rather, we will simply leave the reader our definition of the *glaciosystem* inviting further commentary by those that might be interested in exploring this glacier policy concept. More information on the glaciosystem is available at: http://wp.cedha.net/wp-content/uploads/2012/07/Definicion-de-Glaciosistema-version-1-febrero-2012-english.pdf

Definition of the Glaciosystem (or the Glacier Ecosystem)

The GLACIOSYSTEM (or Glacier Ecosystem) is the glacier and its surrounding ecosystem that influences its constitution and composition, with respect to its water and ice accumulation and ablation, determining its biological process, its natural evolution during its periods of charge and discharge, and which if affected, could impact or cause the alteration of the glacier and/or impact the ecosystem in which it exists.

The glaciosystem (or glacier ecosystem) includes elements such as:

Solids: geological/rock formations surrounding the glacier, whose characteristics and orientation influence in the accumulation of snow, the valleys through which the glacier flows, walls, mountainsides, and the slope on which the glacier advances, rock debris and other natural materials en its vicinity or in its ice, the moraines formed and accumulated by its advancement, among others;

Biological: Flora and fauna and other biological organisms in its immediate surroundings, underneath, beneath and inside of its ice;

Water, Snow and Ice: Snow that accumulates in the glacier through precipitation, water that flows on the surface, inside and underneath the glacier, ice of the glacier with varying densities and in different stages of compacting, other glaciers that unite with the glacier from higher water and ice basins, other glaciers to which the glacier unites, frozen grounds (permafrost) in the periglacial environment, natural or artificial lakes (dams) formed and nourished (even if only partially) by the glacier, natural or artificial melt water at the foot of the glacier;

Air and Atmosphere: The air surrounding the glacier, the atmosphere in the zone of impact that can be affected by artificial changes in the topography that alter the natural wind patterns that contribute to the natural accumulation of water and snow on the glacier, by contamination of the air with particulates that are deposited on the glacier, and that contributes to the natural evolution and of the glacier.

The glaciosystem (or the glacier ecosystem) can extend to zones including:

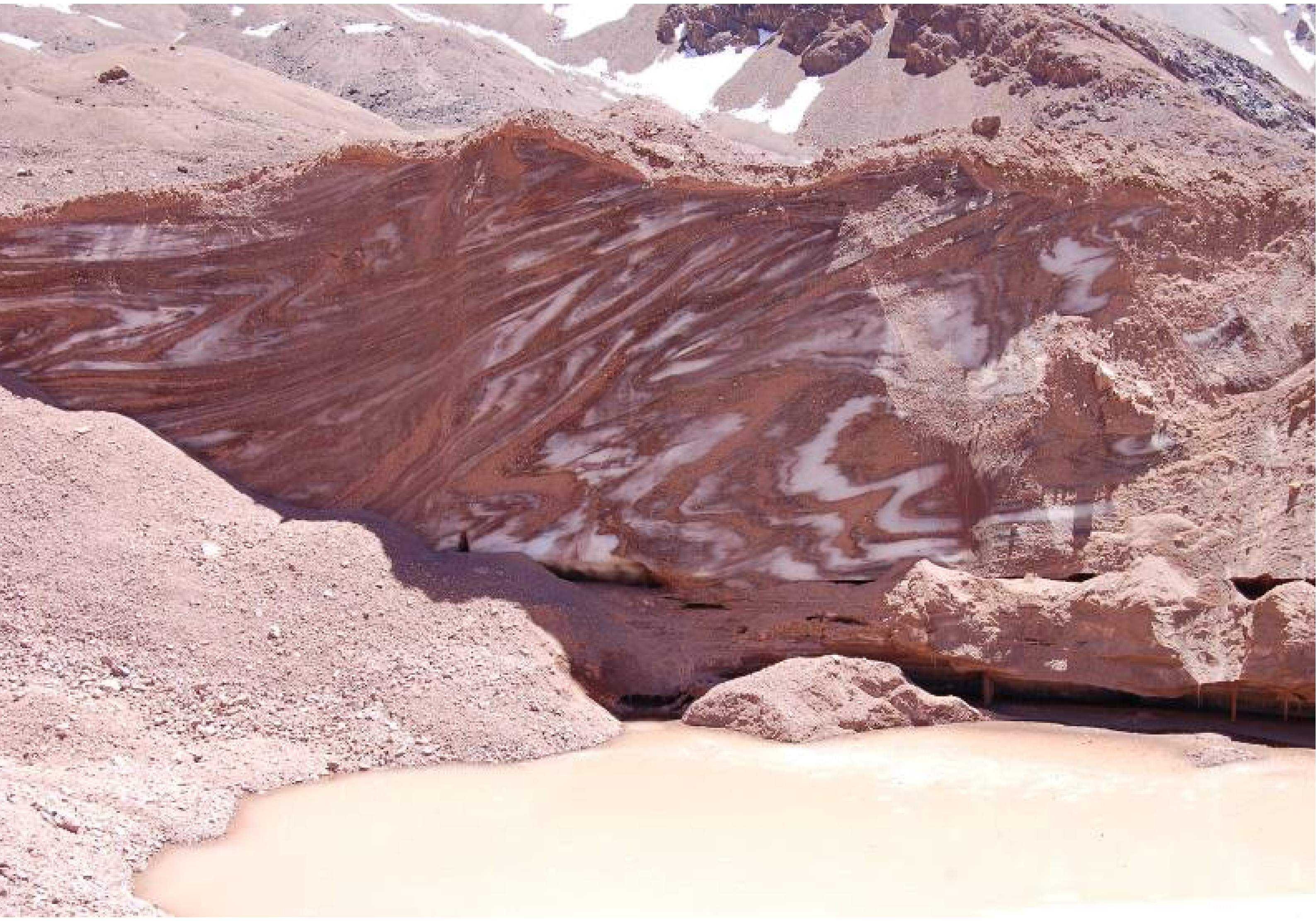
a) in all directions surrounding the glacier;
b) snow and ice on the glacier and to the side of the glacier and water as well as water immediately below the glacier;
c) to the side of and on the valleys through which the glacier flows;
d) in the immediate proximity or at a significant distance to the glacier, depending on the specific case and on the relevance of an eventual impact in the ecosystem of the glacier;

Human populations (rural and urban), agriculture activity and industries that are located in the vicinity of the glacier and that can be directly affected by the changes of the mass of the glacier and on the accumulation and ablation of snow, might depend directly or indirectly on the glacier and glaciosystem.

The health of the glacier and its glaciosystem is evaluated by measuring and monitoring the evolution of the following variables:

Accumulation and Ablation
Line of Equilibrium
Mass Balance
Energy Balance
Temperature
Caloric Balance
Water Flow
Albedo
Impurities/Contamination
Air/Atmosphere in the vicinity

Frozen grounds / rock glaciers; Mendoza. Photo: JP Milana



What is then the Periglacial Environment?

As a first step in the definition of the "periglacial environment" we make two points of clarification on this definition which are fundamental as we approach an understanding of this complex term, particularly if we need to define this term form a public policy perspective to protect this hydrological resource.

1. The lack of scientific agreement on the term. Pablo Milana, in his fabulous book *Ice and Desert: The Arid Glaciers of SanJuan*, initiates his section on Permafrost and Talus Lobes (Milana, p.121) by stating:

   "As there is no agreement on the definition of the term rock glacier, nor do we have consensus with respect to the definition of permafrost".

   Milana is referring specifically to "permafrost" or permanently frozen grounds, which is an key element of the "periglacial environment".

2. *Practice vs. Theory.* Few people have studied the periglacial environment, and fewer still have been able to dedicate field work to the issue, in large part due to the material difficulty of the work. As such we must take into account the theoretical suppositions made by science, but we must also pay close attention to the few individuals who have worked, lived and interacted with

> periglacial environments for many years, since they are of the few people that have been able to observe and measure in person, the dynamics and hydrological characteristics and regulatory function of the resource.

Our definition here opts for a simple and utilitarian approach to the periglacial environment, geared towards an understanding of the resource that will help us devise the public policies necessary to protect the resource and helpful so that we can appropriately apply the law. Subsequently we examine more technical issues related to the periglacial environment offered by science.

Definition of the Periglacial Environment

The Periglacial Environment, very roughly, is the area where because of low temperatura of the environment, generally near 0˚ Celsius or less, the earth is frozen. This freezing could be at the surface, on top of the surface, and/or beneath the surface. The Periglacial Environment is important because if there is humidity in the earth, this humidity freezes (it is transformed to ice). And if there is ice in the periglacial environment, it is a water reservoir, and if this ice melts temporarily or definitely, this ice is converted to water. Periglacial Environments can exist in areas where there is no humidity in which case there is no ice and in such a case it is not a water reservoir. There can be areas in the Periglacial Environment that are permanently frozen (all the time), and others that cyclically unfreeze.

Juan Pablo Milana says wisely, in regards to periglacial environments:

> "what we're interested in knowing is the function of these environments as water reservoirs." (Milana, Ice and Desert, p.122).

Another well known geologist that has studied periglacial environments in Argentina, Dario Trombotto Liaudat, indicates in one of his works that describes diverse forms of the periglacial environment in the region (he is referring in particular to rock glaciers, one of the key elements of the periglacial environment) (unofficial translation):

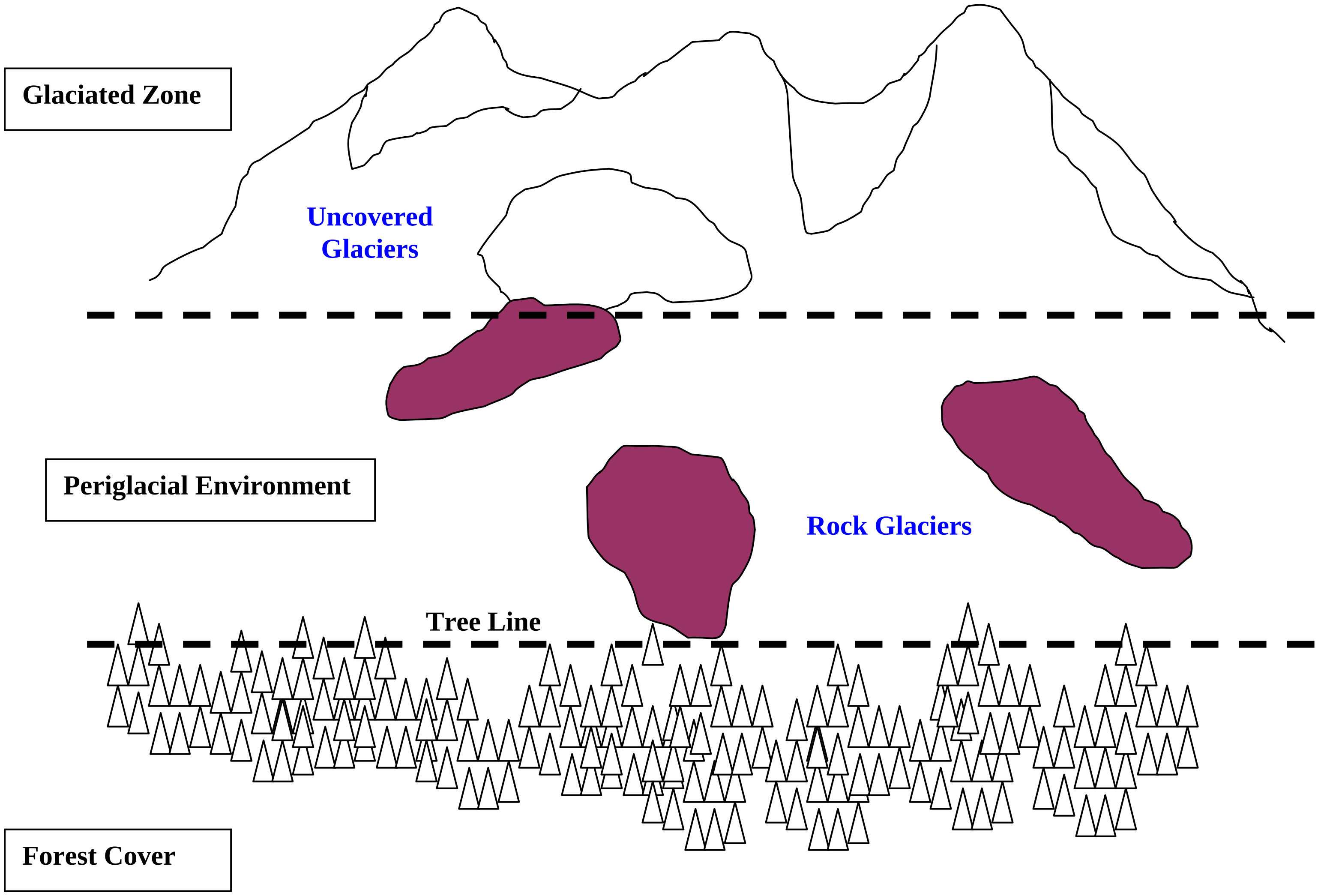
> "[rock glaciers] are surely the most significant cryogenic forms of the Andes. For decades their enormous hydrological value for the Central Andes have been mentioned. … The snow that penetrates the active layer and its freezing creates a system for storing water on high mountain areas. In the summertime, the active layer melts and the discharge into the rivers increases. … The frozen areas, with permafrost or with debris-covered ice in the Central Andes, as in other cryogenic South American regions, constitute more significant water sources than glacial areas." (Trombotto 2000, p.46).

A portion of the water supply derived from periglacial environments comes from rock glaciers that are in the area and that are but one of the elements within the periglacial environment (but not the only element). While much of the ice of a rock glacier may be permanently frozen, if the rock glacier is active (that is, if it is moving), it has an active surface layer. The ice in a rock glacier is water in reserve, while the cyclical melting of the active layer makes the rock glacier function as a water basin regulator.

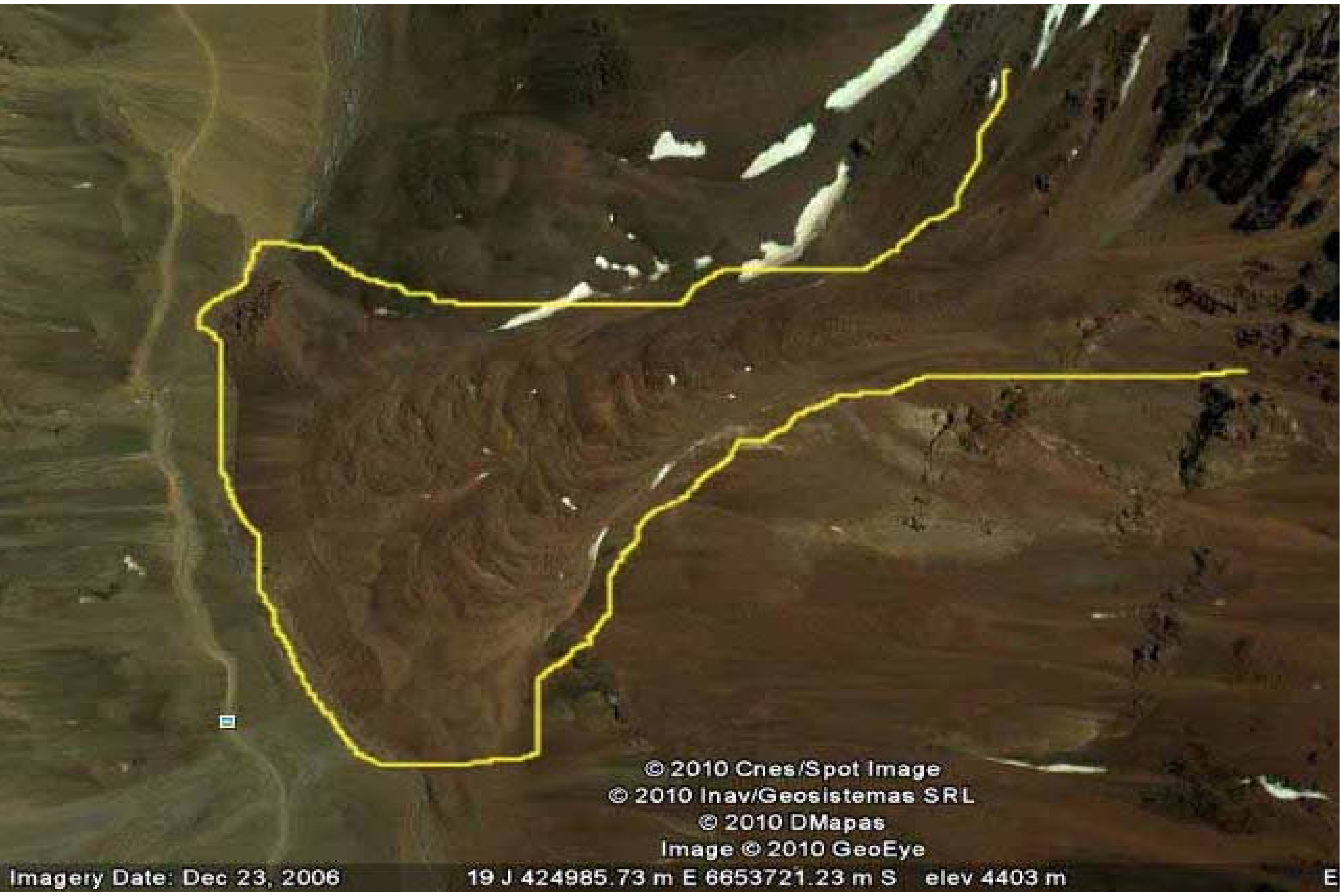
Another expert on periglacial environments, Lothar Schrott calculated for example, that a single rock glacier, the Dos Lenguas Rock Glacier in San Juan Argentina, discharges some 18,000 to 28,000 liters per hour, or 2-3% of the water consumed by a mining project such as Barrick Gold's Veladero. (Schrott, 1994, cited in Trombotto 2000, p.47).

(the reader can see the Dos Lenguas Rock Glacier via *Google earth* at: 30 14 51.83 S, 69 47 5.46 W)

The periglacial environment can be thought of as a geographical strip of land defined by certain geographic and topographical characteristics and by temperature. It is located between the glaciated area and the tree limit line. Remember, Corte tells us that the periglacial environment in the Central Andes is defined vertically as 1,600 meters, ranging from approximately 3,200 meters to 4,800 meters above sea level. The edges of the strip might intermix, but essentially these are the periglacial environment limits for this region. (See figure below).



The Dos Lenguas Rock Glacier in San Juan Province has been widely studied



Sometimes, in very arid areas, at high elevations in provinces such as San Juan, Jujuy, Salta, Catamarca and La Rioja, and even in Tucuman, we do not understand how rivers can have water when the snow has passed and we can no longer see ice or there is no rainfall. Nonetheless the rivers may have water, in the middle of drought, even if it is a small amount. In these places, where there are high mountains that surpass 3 or 4 thousand meters, it is very probable that the earth conserves ice in its interior, below the surface. The gradual melting of this ice, at the lower elevations of the frozen grounds, spurred by the gradual temperature rise in the early summer, is the source of water. There possibly, and luckily, we are likely to find a *periglacial environment*.

Frozen ground reveals ice. Source BGC
(Casale study, p.41)

The periglacial environment is hence an area where the earth is at 0˚C Celsius or less and where there may be ice below the surface of the earth. And when there is ice present, it is this ice that we want to preserve.

Let's consider then a more scientific definition offered by the IANIGLA, the Argentine national glacier institute. The IANIGLA defines the periglacial environment as (unofficial translation):

> … a cold climate environment, non-glacial, which is found above the forest line, if the forest line exists, and that is characterized by
>
> - The occurrence of permanently frozen grounds or permafrost
> - Preponderance of freezing and unfreezing cycles that affect rocks and the surface layer of the ground, and of periglacial processes that generate cryoforms

Lets take this definition apart to understand the technical aspects it is referring to.

Cold Climate*: It has to be cold. Scientists want 0˚ Celsius to speak of periglacial environments.* Why 0˚C? Simply because it's the temperature at which water freezes (unless there is mineral element in the water that might lower its' melting point (such as salt). When the humidity in the earth freezes, the earth itself becomes a water reservoir, conserving the water, as if it were a glacier. If the ice melts (if its' temperature rises above 0˚ Celsius, water is discharged into the ecosystem. We should stress that 0˚ C is a reference, as periglacial environments can have maximum temperature areas that range from -1˚C to 3˚C, according to select scientific references.

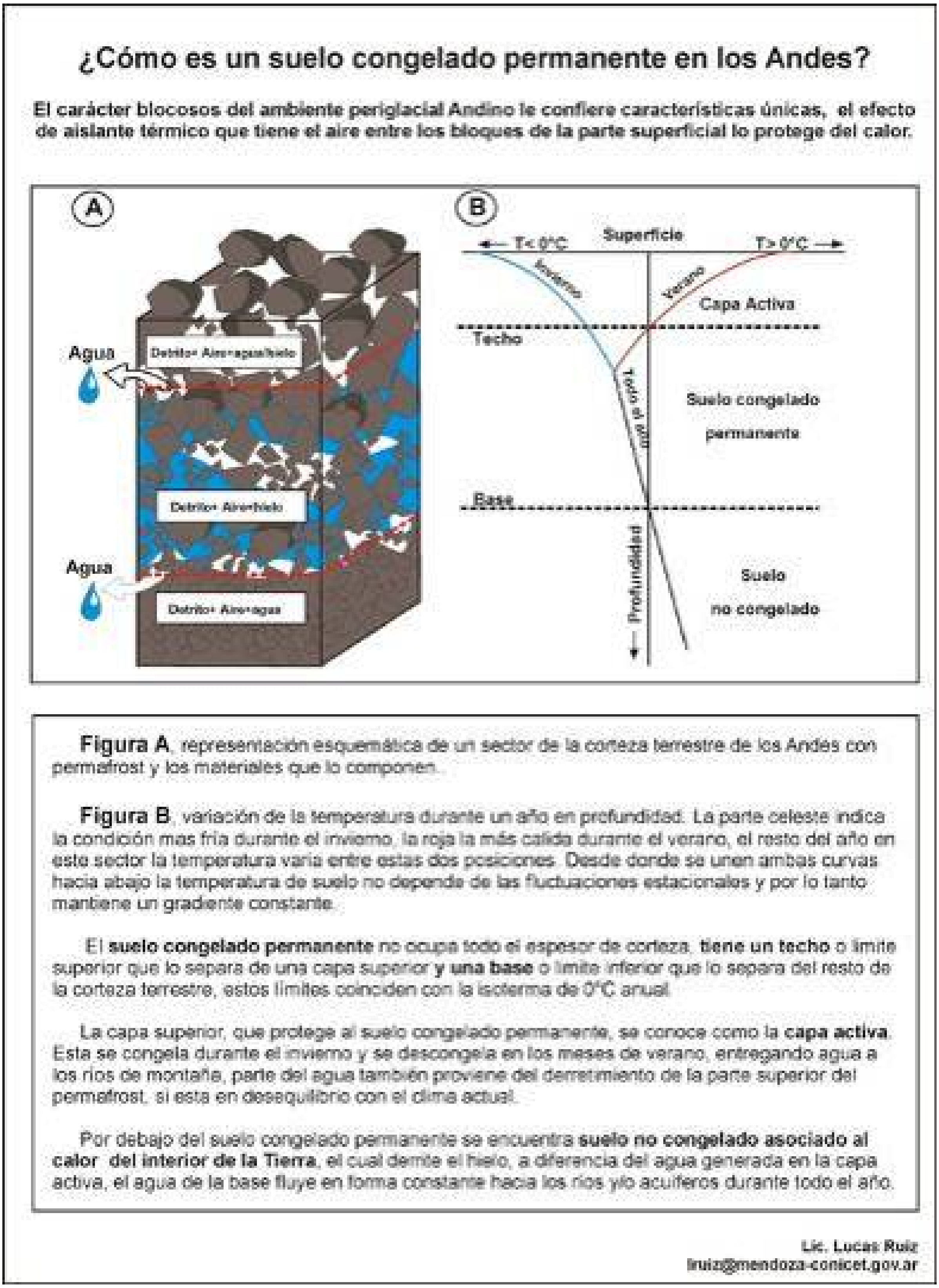
If we are in a mountainous area, as we go higher in elevation, it gets colder. Eventually, at much higher altitudes (in San Juan at about 3,500 meters more or less), the average yearly temperature is at 0˚ C or lower than 0˚ C. That is where we can find periglacial environments, which are precisely frozen grounds where the temperature is below 0˚ C for most of the year. We should consider that the temperature of a given area can rise for undermined periods above 0˚ C, but the average yearly temperature should keep below this marker if we are to speak of the periglacial environment, and it should not ever melt completely. We should also consider that in a single mountain we can have areas where the ground is frozen and remains frozen, and other areas where it does not. There may be micro-climates that exist due to solar exposure and in such cases, for example, we might find that south-facing mountainsides (facing the South Pole) will be colder than those that face North, where the sun is for most of the day. This is why periglacial environments tend to be on mountainsides that are cooler, for example, those facing South. In the Northern Hemisphere, this characteristic is reversed.

Non Glacial: With this characteristic the IANIGLA distinguishes between glaciers and *periglacial environments.* That is, for the IANIGLA, *a glacier is not necessarily a part of the periglacial environment.* We are speaking of an area beginning at its low point where the soil is frozen, up until the point where we begin to see uncovered glaciers. This point however could be debated, since not all scientific opinion is the same on this issue. Some specialists consider that some of the elements of the periglacial environment (such as a debris-covered glacier or a rock glacier) can be considered glaciers since their characteristics are very similar or identical to common uncovered glaciers. In any event, this difference is a semantic difference which we will not attempt to resolve. We are interested instead, with the protection of ice and with the application of the National Glacier and Periglacial Environment Law, and as such, whether or not we call the elements within the periglacial environment *a glacier* or not, if they have ice, they are of concern to us and they are protected by the law to the same extent as if they were common uncovered glaciers, with no distinction as to whether they are uncovered, covered, rock glaciers, or whether they are active or inactive, or if simply the area is periglacial environment without glaciers. They are all equally protected by the law.

Above the Forest Line: This point has to do with the presence of vegetation in the environment. The basic idea that underlies this point is that where the environment is permanently frozen, that is, in the periglacial environment, vegetation does not survive, at least not common trees and other plants that live at warmer elevations. This phenomenon/characteristic is not necessarily due to the inability of plants living at temperature below 0˚ C, but rather because of the elastic properties of water to ice transformation. As water changes to ice and its volume stretches, this alters the ground generating soil instability which does not allow for the proliferation of flora. (Corte 1983, p.338). Some studies have revealed biological life within ice, but for the sake of this discussion we will assume that in the periglacial environment, we don't find trees or plants. Everything is frozen. If we see lots of living and active vegetation in a given area, then we can presume we are not in a permanently frozen area. We should be careful about this presumption however, as we may find flora on the fringes to periglacial environments, where we may have discontinuous permafrost phenomenon occurring (that is, that it melts cyclically).

Permanently Frozen Grounds (Permafrost): For many, although not for all, these terms are interchangeable. This can cause some confusion, particularly when we use the terms as synonyms. The term *permafrost* has two parts. Perma = permanent, and frost = frozen. Scientists generally accept the existence of permafrost when freezing occurs for at least two or more consecutive years. This implies that the earth, that rocks, that all of the ground is at 0˚ C or less, which means that if there is humidity present, if that water has seeped into the earth or between the rocks or if snow or rainfall has entered to the earth, this humidity it is frozen and it remains frozen for at least two years. If an environment is at 0˚ C or less, we presume that the environment is frozen, whether or not it has water content. Corte, the geo-cryologist, expert on permafrost, estimates that in fact, for permafrost we need that the ambient temperature goes below -1.5˚ C, on a yearly average (Corte 1983, p.289), for the grounds to be permanently frozen. In this regards, frozen grounds (or permafrost) have to do with temperatures that should be at 0˚ C or less. Evidently, we are much more concerned with permafrost from a hydrological perspective if it has humidity. But technically, we can have permafrost without ice. In simple terms, *permafrost has to do with temperature, not with water* and we can have permafrost **without water**. We shall see that for many scientists, rock glaciers (that are a mix of rock and ice) are considered permafrost. That is, rock glaciers, are a type of frozen ground (a type of permafrost), that are located in the *periglacial environment*. They are not the only elements of the periglacial environment, but they are of great significance.

Cyclical Freezing and Unfreezing: The idea here is that the rock and earth material near the surface in the lower altitude limits of the periglacial environment, freezes and then unfreezes. That is, there are moments when the temperature is above 0˚ C, and the ice present (if there is any) at that point is converted to water. We are hence dealing with a variable characteristic which can have distinct conditions at different depths. At one point as we go below the surface of permafrost areas, we come to an area where the ground is permanently frozen and never melts. This in reality the real permafrost, always frozen. The higher layers that suffer cyclical freezing and unfreezing, are called the *active layer*. This layer is in a state of constant flux and movement. Below we reproduce a figure taken from the IANIGLA website, which illustrates the different layers of frozen grounds.



Periglacial Processes and Formation of Cryoforms: The idea we capture from this characteristic is the concept that something is occurring during the interaction of the natural elements (including ice, rock, earth, etc.) that generates certain types of geoforms with ice and rock, specific to the periglacial environment. We will see that we are speaking in this case of the different types of rock glaciers.

Up until now we are discussing the definition of the *periglacial environment* offered to us by the IANIGLA, which is significant since the National Glacier Law calls on the IANIGLA to carry out activities to protect glaciers and the periglacial environment, including carrying out an official national inventory of the periglacial environment. However, when we begin to talk to different scientific experts that study the technical aspects of the periglacial environment, we begin to see that there are many interpretations of this information, which broaden or even contradict these concepts. The important thing to understand is that there is no single accepted definition on the issue. Glaciers and the diverse forms of ice that is studied by cryogeologists are the subject of evolving study.

As a central axis of our debate, it's important to consider that we should be focused on the ice/water content of the periglacial environment, since it is this environment that acts as a water reservoir and that also is cyclically available to future water needs by nature or by communities.

Image: Frozen grounds with high ice content: Source: JP Milana

Periglacial Environment in San Juan – High ice content. Source: JP Milana

Slope showing “gelifluction” recognizable by small crests, indicates probable presence of frozen grounds. Source: BGC/Casales p.55

A few other concepts for further precision of the periglacial environment

Dario Trombotto Liaudat, adds on the IANIGLA wesbite on periglacial environments, that these also manifest the "occurrence of deep permafrost" … with "possible presence of subsurface ice trapped and preserved … for long periods of time". He also adds that it is marked by the "dominance of freezing processes, with freezing and unfreezing cycles" and with "the "presence of solifluction and gelifluction on the surface". He is telling us that the ice can be a possibly significant depths below the surface of the earth, and that both the rocks and the ice, are part o this periglacial environment in motion.

Trombotto also calls our attention to a difference between points of view on the North vs. South exposure of mountainsides to solar impact in the Andes, in regards to permafrost presence. Southern facing mountainsides can include permafrost more easily depending on exposure, altitude and microclimates. Trombotto also clarifies a key point in this discussion, which is that water can exist at temperatures below 0˚ C, and as such, says Trombotto, while "all permanently frozen ground [always frozen] is permafrost, …. not all permafrost is permanently frozen." For this reason, he suggests that "permafrost should not be considered permanent, since changes in climate in geological history or those induced by man, can cause an increase in the temperature of the ground and affect it." In this regard, permafrost is an unstable resource, and can be providing water or not according to the present condition.

Trombotto states that rock glaciers are periglacial environment cryoform elements, the most important of the Andes:

> [The rock glacier] is a cryoform that presents evidence of past or present movement. The rock glacier is a cryogenic mesoform of mountain permafrost, saturated with ice, which is active, moves down slope due to gravity, reptation and deformation of the permafrost.

He also makes a very point in terms of the hydrological value of these cryoforms:

> "Rock glaciers don't form where there is not sufficient humidity to form interstitial ice that permits the deformation and movement of the cryoform" .

Essentially, the presence of water/humidity is key for the formation of rock glaciers.

The periglacial environment has layers or process levels in the ground, that can be active or inactive from a dynamic perspective. The active layer (the most superficial layer) has freezing and unfreezing cycles. The ice that forms in the winter and in the colder months, melts during the warmer months. This is what we call the "water regulating function", releasing water during hotter months, deriving from the ice that formed during colder months and that entered into the ground due to precipitation. This is a natural cycle very adapted to the necessities of the local ecosystems of the region, which if they did not exist, and if we did not have glaciers or periglacial environments, we would not have water in the summer time.

Can We Identify Periglacial Environments with Satellite Images?

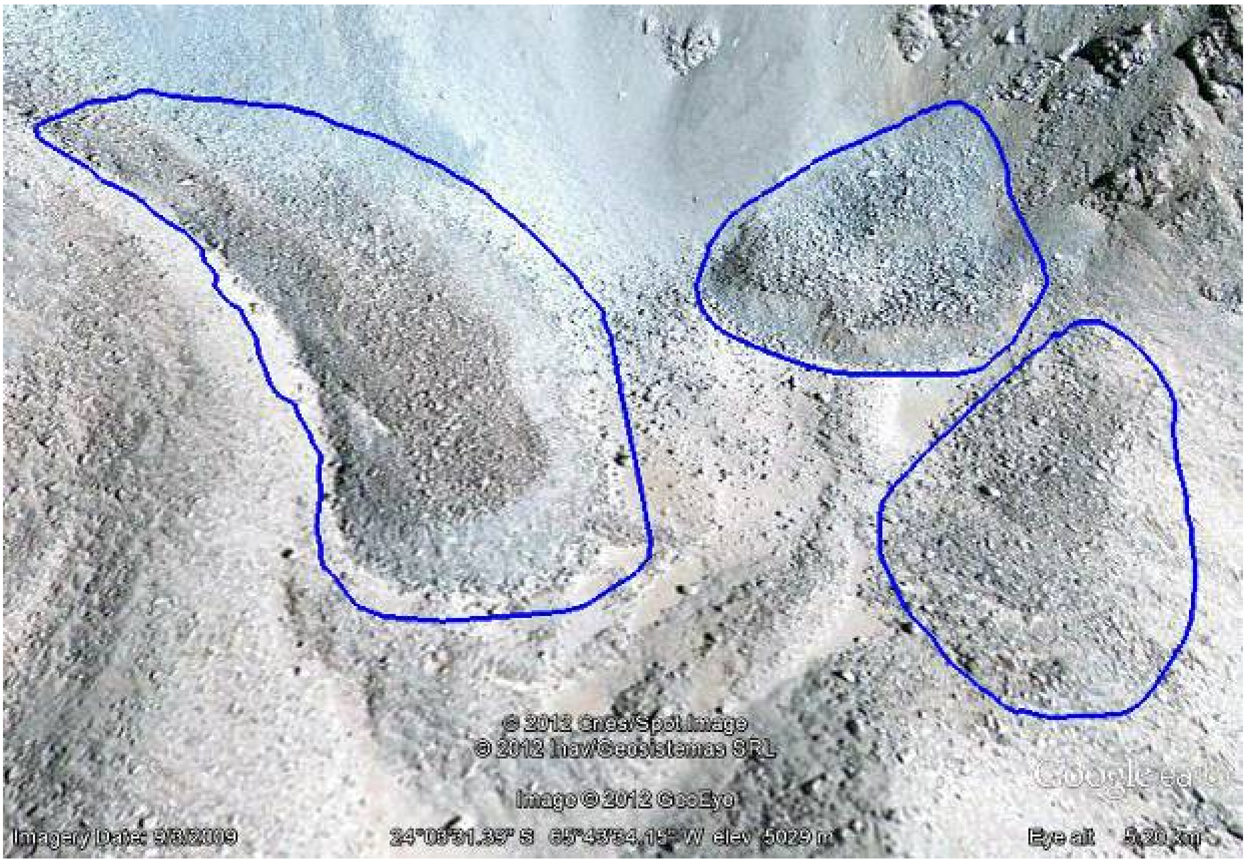
Yes we can. There are some clues that reveal these environments, although we cannot always see them.

First we must refute statements by those that say that you cannot see periglacial environments via satellite images. This is simply untrue. The freezing of the surface of the Earth and of water creates fissures and orders rocks on the surface in systematic forms which are reiterative, and this systematic sorting created by freezing processes is precisely what we can definitively distinguish from high above.

In the following image we see frozen grounds (in Svalbard Norway) where rocks have been ordered in a very particular fashion (in circular patterns). This sorting has to do with the physical properties of freezing processes and how these affect loose rock.

Frozen grounds leave rocks in orderly distribution in circular forms. Source: Hannes Grobe.

In the following image for example, of the mountains of Jujuy Province in Argentina, (visible via *Google earth* at: 24°03'31.39" S 65°43'34.15" W), we see rocks sorted on a mountainside. We notice that there seems to be order to these rocks; they are not randomly distributed. These grounds are frozen and the ordered rocks are part of a rock glacier. The two formations on the left which we've indicated with blue polygons are characteristic of rock glaciers, with an abrupt 30-40 degree linear break at the lower end. The third polygon on the right is not so clear, as it lacks this abrupt linear ending, but could nonetheless be a rock glacier. The three polygons (rock glaciers) have movement in a downward direction.



Ordered rocks reveal frozen grounds (rock glaciers) in Jujuy. Source: *Google earth*

There are cases where we cannot visually confirm the presence of periglacial environments, but in others, it is very clear. In other case we can infer the presence of periglacial environments, as there are elements of the periglacial environment which are evident in the area (as for example, active rock glaciers), or the ordering of rocks in a particular fashion. The mere presence of these characteristics permits us to conclude that we are indeed in a periglacial environment.

One of these elements is the presence of rock glaciers.

Rock glaciers appear in areas where the ground is permanently frozen; they are part of the periglacial environment. The glacier experts, Barsch and Haeberli established in the 1970s the “indirect” method of identifying periglacial environments by observing rock glaciers.

Another method is by observing other typical characteristics attributable to frozen grounds that will also indicate to us that we are likely in a periglacial environment.

Stripes (wrinkles). Milana tells us that “the most common morphology that helps us identify frozen grounds is the formation of stripes, or “wrinkles” on the surface”. These wrinkles from due to the movement of the ground which is possible due to the plasticity of the ice and gravity acting on the ground due to the inclination of the mountainside. (Milana, Ice and Desert, p..122).

The two following images are indicative of how satellite images can help us identify frozen grounds. The first photo is a picture taken at the site, the second is a how this ground looks from a satellite image capture that we can see on *Google earth*. Clearly, we can see these wrinkles via satellite. We may not be able to determine the presence of ice, but we this is an indicative feature that at the very least merits further inspection of the site for verification.

Photograph of stripes or “wrinkles” in a periglacial environment. Photo: JP Milana

The same location as viewed in *Google earth* confirms that we can see certain periglacial environments via satellite.

Accumulation of water at the base of Periglacial Environments. Where there is a periglacial environment that is functioning as a water basin regulator, due to its freezing and unfreezing of active ground layers, it's very likely that we will find water at the lower levels of the periglacial environment, in the form of lagoons, or small streams of water feeding larger streams, etc. In the following image, near the El Pachón mining project (Xstrata Copper), we see a lake form at the base of rock glaciers (these rock glaciers are descending down the mountainside). The forming of these lagoons is a typical characteristic at base of a periglacial environment. If in the summertime, these lagoons are frozen, it's very probable that we are at 0˚ C or less and hence we would be in a periglacial environment. If there is freezing and unfreezing occurring, then we are likely to be in a discontinuous permafrost zone.

Lagoon forms at the base of a periglacial environment with a rock glacier visible immediately above the lake.
See via *Google earth* at: 31°43'15.15" S 70°27'30.16" W

The Periglacial Environment and its Importance to Ecosystems

Corte recounts that the original inhabitants of the region, the Incas, had learned to use frozen grounds. They stored fresh foods below the earth's surface at elevations where the ground offered natural cooling. We do the same when we go skiing, or if we live in cold climates, when we leave food products outside a window when the outdoor temperature is near zero degrees.

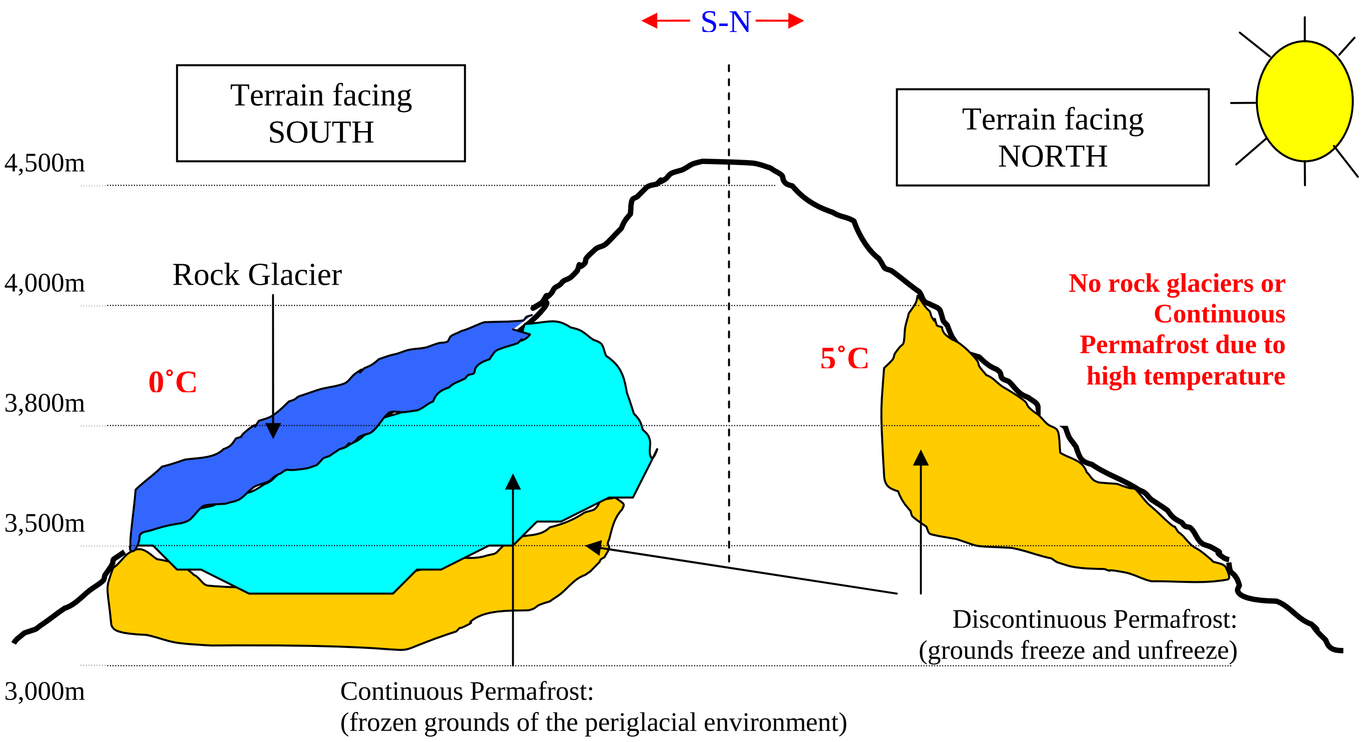
Perhaps what is most important of the periglacial environment, is not its' low permanent temperature, but rather it's lower elevations, which go through cyclical freezing and unfreezing processes. These freezing and unfreezing cycles are what provides water to our ecosystems when they need it most. They are especially important to dry/arid regions like San Juan, Salta, Catamarca, La Rioja, and Jujuy. In these "unstable" areas, of the periglacial environment, the ambient humidity is frozen when it is very cold, and then it unfreezes when the temperature rises. This is precisely the process we refer to as the "regulation" of water basins provided by frozen grounds. Corte, speaking of "drainage" from frozen ground areas, (permafrost), says wisely, "The drainage from a permafrost region takes place through the active layer. Snow that melts, …. if there is a higher temperature in summer that can melt the ice in the permafrost, flows through the active layer; which is very thin in a few decimeters, the flow can be very significant." (Corte 1983, p.306). This is precisely the reason why the National Glacier Law protects the periglacial environment.

Because the periglacial environment is a water reservoir and regulates our water basins!

There are places where this cyclical freezing and unfreezing occurs in a single day. At night time, the water in a stream freezes, and during the day, it melts and generates water flow. The same thing can occur in a periglacial environment. The humidity generated at the surface can freeze at night, and contribute water during the day.

These processes can also be seasonal, that is, in winter time water in the environment freezes during the entire season (night and day) and in spring time or in summer, it melts for several months. This can also occur on single mountainside, depending on the solar exposure of the terrain. There might be parts of the terrain that remain frozen and others that go through melting cycles. In the Southern Hemisphere, in the Central Andes for example (above 3,500-4,000 meters), the northern facing mountainsides unfreeze and release water, while the South facing mountainsides, remain much cooler or frozen.

The following image offers a schematic generic description for a mountain in a periglacial environment area. We've cut the mountain in two (without causing any impact!), to depict the cold and warm areas in the terrain. The example would be for a summer month at approximately 3,200-4,800 meters. It could be a mountainside in San Juan, Catamarca or La Rioja. The South facing side of the mountain, because it remains largely in the shade, despite it being summer, maintains a 0˚C temperature or lower. For this reason, we see that there are rock glaciers (dark blue) present as well as frozen grounds (light blue) of the periglacial environment. There may be lower areas where there are cyclical freezing and unfreezing processes (a few or many times during the year). These would be called discontinuous permafrost zones and these may manifest a large water contribution to steams below. Most of the ice in this latter case would disappear by the summer.



We should keep in mind that this scheme is merely a generic case, since permanently frozen grounds might exist on Northern facing mountainsides (at higher altitudes).

The geologist and glacier expert, Ana Lia Ahumada, who has studies periglacial environments in provinces such as Jujuy, Catamarca and Salta, tells us of the fundamental role played by ice and by frozen grounds, for communities in North-Western Argentina.[3] (unofficial translation)

> The percentage of ice in rock glaciers varies between 40% and 60%. For this reason, they are considered to be important freshwater reservoirs in high mountain altitudes and part of the water-cycle of arid and semi-arid regions where we find productive mountainous valleys of Northwestern Argentina.
>
> [various rock glacier basins in the Argentine Northwest] are linked to the generation of hydroelectric energy or to irrigation and freshwater provision networks. [Others] permanently feed productive valleys in highlands. In synthesis, we could say that in Northwestern Argentina, rock glaciers:
>
> - Are located at the head of basins that generate electricity, irrigation water and freshwater
> - Are the regulatory source of water resources for highland communities in border areas of the country and constitute as such an important strategic resource
> - Permit the establishment of communities and production in the high mountain valleys with the application of ancestral knowledge from local indigenous cultures and the cultivation of agricultural products native to this highland area …
>
> A glacier inventory should be carried out not only for these reasons, but because of global warming, and the resulting increase in need for freshwater, announced for the XXI Century, all motives that result in the need for a registry of this important strategic hydrological resource.
>
> The inventory is a necessary tool for disaster prevention, to carry out territorial planning, development, vulnerability analysis, management, legislation and the economy of water.

[3] see: http://www.glaciares.org.ar/categorias/index/nota-noa

Corte stresses that in areas such as in the Puna, highland area of the North of Argentina, the daily freezing and unfreezing of rivers is a fundamental process in for water conservation in periods of the year where we most need water rationing (this is the function that the National Glacier Law calls "regulation of water basins").

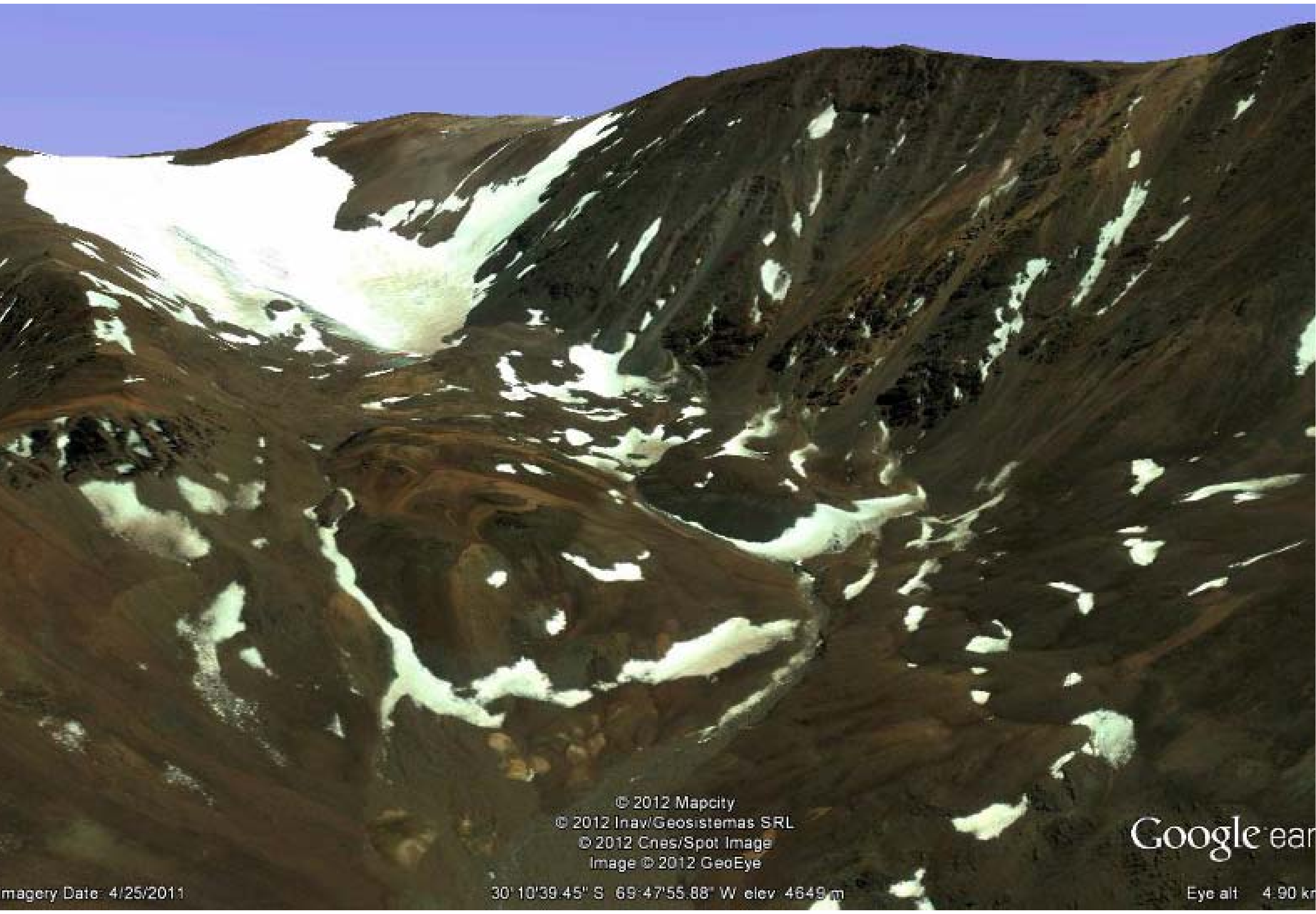
> "Catalana (1927) provides a description of the rivers of the Puna, which "run with the clock": They commence their flow at 10 in the morning and then dry up at 4pm. These daily surges of the rivers in the Puna, are due to the freezing of springs during the night and their melting during the day … The frozen spings occur in the Puna's dry season, during the winter, when it water resources are most necessary. When considering planning, the cryogenic factor of this resource is of great importance." (Corte 1983, p. 351).

Marangunic (one of the most knowledgeable Chilean rock glacier experts) and Corte (an undisputable voice on the subject) who studied the Central Andes, showed the enormous importance of rock glaciers (and of the periglacial environment) in terms of their hydrological value. According to Marangunic (1976), "you can expect that one km² of rock glacier contributes a flow of 30 liters per second. (Corte 1983, p.349).

Trombotto summarizes Schrott's work (1994) revealing some impressive data on the hydrological contribution of rock glaciers:

The Dos Lenguas Rock Glacier, San Juan Argentina, contributes 5-8l/s

- The *Dos Lenguas* rock glacier discharges 18,000 – 28,000 liters per tour (or 5-8 liters/sec); you can see this glacier at: 30 14 51.83 S, 69 47 5.46 W (see picture to the left)
- The upper basin of the *Agua Negra* glacier with 2 km² of rock glacier contributes some 180,000 liters per hour (or 50 liters / sec); see: 30°10'30.16" S 69°47'53.84" W
- While the Morenas Coloradas basin which contains rock glaciers and frozen grounds, is the source of the Vallecitos river, with 1,818,000 liters pe hour (or 505 liters / sec), vital to provide water to the population of Mendoza; see: 32°57'15.00" S 69°22'16.75" W



Rock glacier and Periglacial Environment system (Agua Negra) contributes some 180,000 l/hour. San Juan Argentina; see: 30°10'30.16" S 69°47'53.84" W

We've heard on occasions the opinion that glaciers do not contribute water. That snowfall on glaciers is lost due to sublimation (evaporation), so that it actually never is converted to water and simply vanishes into thin air. Corte makes reference to the sublimation of snow/ice in his 1983 work, but he makes an important point of clarification that those suggesting that glaciers don't contribute water leave out. Corte distinguishes between an uncovered glacier and snow, from the ice contained in a rock glacier of the periglacial environment. (unofficial translation)

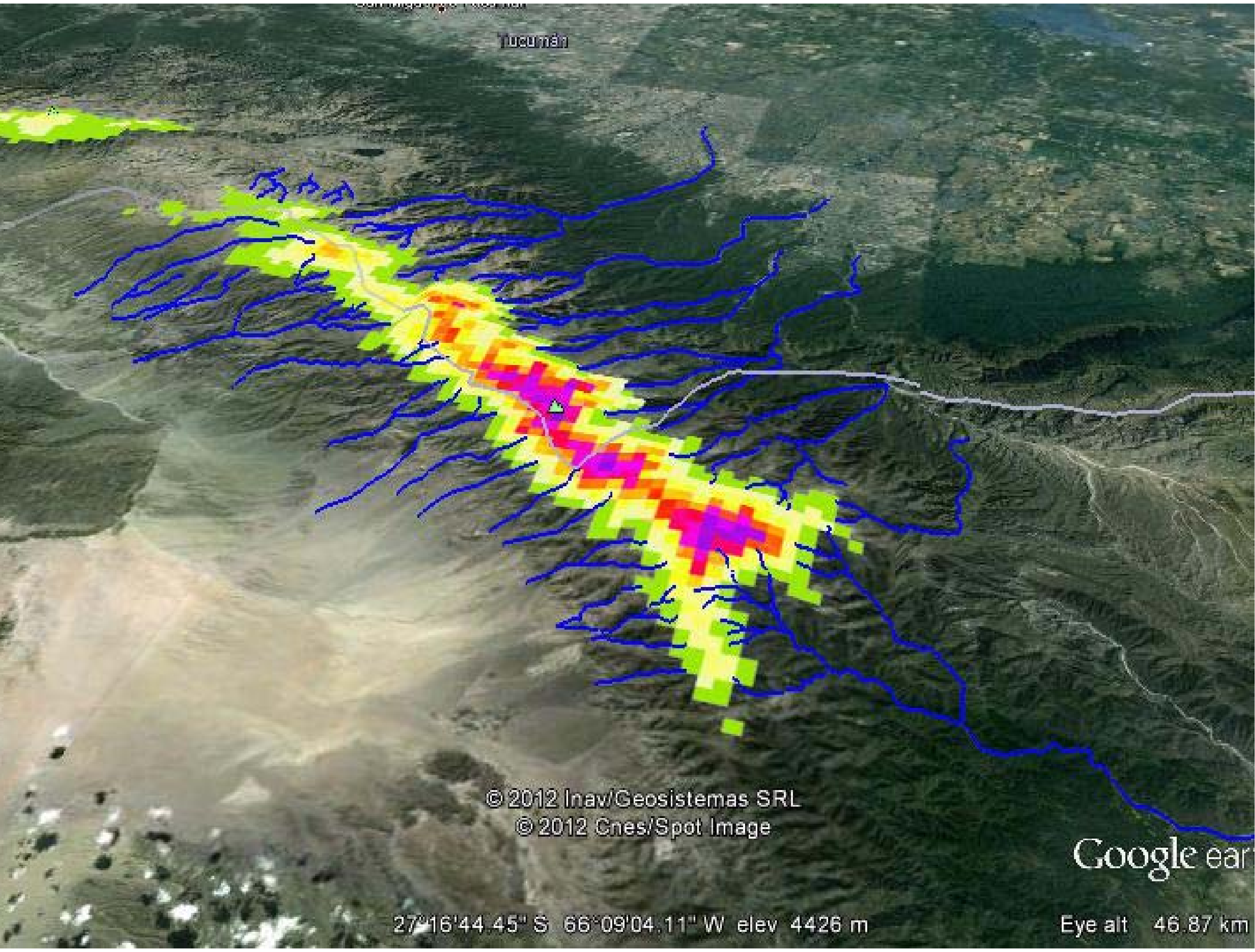
> "The rock cover must play an important role in the provision of water for several reasons: its surface is irregular and jagged, serving to trap snow and at the same time, this snow melts in between edges of rock and is re-crystallized further below. At the same time, the movement of the cover must melt snow inside the rock glacier. In this way, the loss by sublimation and evaporation, that are so significant in these dry areas, is impeded in these bodies." (Corte 1983, p. 350)

Additionally another aspect is ignored in this analysis suggesting that the sublimation of ice (the passage of ice directly to a gaseous state) which is while it may not directly contribute water to by melting, it does contribute to the humidity of the atmosphere, which in turn returns to the ground in the form of condensation or rain.

Hence, the affirmation of some that the ice contained in periglacial environments (in rock glaciers) or snow that falls on these glaciers, evaporates and does not contribute water to the ecosystem. *On the contrary!* Rock glaciers (with debris on the surface), contribute water directly and indirectly! And further, even the portion that sublimates can return to the ecosystem in some other form of water.

As a last point from Corte's work, which is also important to stress, rock glaciers are nourished by water and snow coming from higher up the mountain. For this reason, every ice body is important, including ice patches, perennial ice, etc. that is above the debris-covered glacier. Any impact to these resources located above the rock glacier and above the periglacial environment area, should be avoided.

The following image shows the undisputable relationship between frozen grounds and the rivers of the Aconquija range.



The National Glacier Law and the Periglacial Environment

We've already indicated that the National Glacier Law protects both glaciers and periglacial environments because they are both important water reservoirs and as such they are strategic resources, and because they regulate water basins. The inclusion of the periglacial environment as a protected area was by recommendation of the IANIGLA, because they understood the importance of the periglacial environment in terms of its hydrological value and as a water basin regulator.

So in addition to protecting glaciers, the law establishes that periglacial environments should also be protected.

Article 2 of the federal law 26.639, "Minimum Standards Regime for the Preservation of Glaciers and Periglacial Environments", states (this derives from an unofficial translation of the law):

> … Detritic rock material and internal and superficial water streams are all considered constituent parts of each glacier. … we understand by the periglacial environment of high mountains the area with frozen ground acting as regulator of the freshwater resource. In middle and low mountain areas, it is the area that functions as regulator of freshwater resources with ice-saturated ground.

This paragraph of the law clarifies that we should protect and conserve frozen grounds that function *as regulators of water resources*. By this definition, frozen grounds without water content would not be protected. We should remember that *permanently frozen grounds (permafrost) has to do with a state of temperature, not water content. There can be permafrost without water.* This is an important point to stress, in terms of the protection of the hydrological resource en the permafrost and also at the moment of defining what needs to be registered or not. Furthermore, we note that this paragraph of the law mentions *the periglacial environment in general*, and not a single part of it. It is not referring only to "geoforms" of the periglacial environment. It would be erroneous to suppose that in the periglacial environment only rock glaciers are protected (which are but one element of the periglacial environment). For this reason, we conclude that the national inventory, should also register frozen grounds with no glaciers.

In Articles 3 and 4, we have more clarity about what should be inventoried, specifically:

> "all glaciers and periglacial landforms that act as freshwater reserves on national territory shall be identified along with the pertaining information that is necessary for their adequate protection, control and monitoring." (Art. 3) and …
>
> "The National Glacier Inventory shall contain information about glaciers **and the periglacial environment** by watershed, by location, by surface area and by morphologic classification of the glaciers **and periglacial environment …** verifying changes in the area of glaciers and the **periglacial environment**, their advance or retreat, and other factors that are relevant to their conservation." (Art.4) (emphasis added)

We've already stressed that a rock glacier is a geoform which is *one* of the possible components of the periglacial environment. But periglacial environments exists without rock glaciers (active or inactive). Article 3 aims specifically at the "individualization" of these geoforms, as glaciers and rock glaciers (active or inactive). The "individualization" of these leads us to presume that we are identifying and counting independent ice bodies, but not necessarily identifying frozen areas with no glaciers. Article 4 resolves this problem, since it is more general in establishing that the inventory should "contain information … of the glaciers and periglacial environment." (Art. 4) In this article there is no mention of specific geoforms of the periglacial environment, and as such, we understand it to refer to the periglacial environment generally.

In each of Articles 3 and 4, the text mentions "necessary information" of the "relevant factors" for the protection of the resource. In this regard, clearly, the identification, registry and monitoring of the frozen ground areas and periglacial environments more specifically (whether it has glaciers or not), becomes essential to achieve the effective protection of the resource.

Article 5 reiterates the need to monitor "the state of the glaciers and the periglacial environments".

The National Glacier Law establishes the protection of any geoform in the periglacial environment zone that contains ice. That could be an active rock glacier (with movement), or an inactive rock glacier (without movement, but with ice content). This is an important point since many of the provincial glacier laws distinguish the features that are in the periglacial environment and leave out inactive rock glaciers that can contain a significant amount of ice.

The difference between active rock glaciers and inactive ones is that the former has movement and is in constant regeneration. The active rock glaciers is nourishing itself with new ice at least in its superficial active layer, while it may have older and more stable ice in its interior. The active layer is moving forward, downslope due to surface inclination, and it's cyclically regenerating. Also, the active rock glacier might have ice that originates in a higher elevation uncovered glacier, in which case, it is even more dynamic in terms of movement.

In the following images we see a complex glacier system in the Tupungato, Mendoza region. It is the Cerro San Juan, where we can see the transition from an uncovered glacier to a rock glacier. You can visit the glacier site on *Google earth* at: 33°29'32.04" S 69°47'48.31" W)

Complex glacier system. Transition from uncovered glacier to debris-covered glacier. - Cerro San Juan, Mendoza. Photo: Horacio Osorio

The inactive rock glacier is deteriorating, and may be close to its end, which leads us to another question: Is it melting? in which case, the inactive glacier is actually contributing a positive balance of water to the ecosystem. While this inactive rock glacier survives, it can also be an important source of water.

The problem with some of the provincial glacier laws, for example the provincial glacier protection law of San Juan, is that they ignore the hydrological value of inactive rock glaciers, as if they were not water providers. In this regard, the National Glacier Law is much more effective to assure the protection of all of the ice mass in the form of glaciers, or of the periglacial environment, both due to its role as a water reservoir as well as in terms of its water basin regulatory value. Inactive rock glaciers, in this regard, are just as important as other active cryoforms.

According to Article 4, we should register the periglacial environment by watershed, by location, by surface area and by morphological classification. This implies stating whether the body is an active or inactive rock glaciers, or if it is simply frozen grounds (permafrost). The inventory needs to be updated every 5 years. This information is critical since it allows us to determine which periglacial environment contributes to which watersheds. While it is very possible that we'll never know just how much water is provided by a periglacial environment, we do know that it total, the contribution can be very significant, more so when it has been an especially dry year.

Article 6 of the law, on Prohibited Activities, which generated much controversy, due to the prohibition of mining activities, also mentions the periglacial environment, and established prohibitions specific to this environment, namely in paragraphs a) and c). Paragraphs b) and d) could also apply to the periglacial environment but they do not make explicit reference to it.

> **Art. 6º –** Prohibited Activities
> All activities that could affect the natural condition or the functions listed in Article 1, that could imply their destruction or dislocation or interfere with their advance, are prohibited on glaciers, in particular the following:
>
> a) The release, dispersion or deposition of contaminating substances or elements, chemical products or residues of any nature or volume. Included in these restrictions are those that occur in the periglacial environment;
> b) The construction of works or infrastructure with the exception of those necessary for scientific research and to prevent risks;
> c) Mining and hydrocarbon exploration and exploitation. Included in this restriction are those that take place in the periglacial environment;
> d) The installation of industries or the building of works or industrial activity.

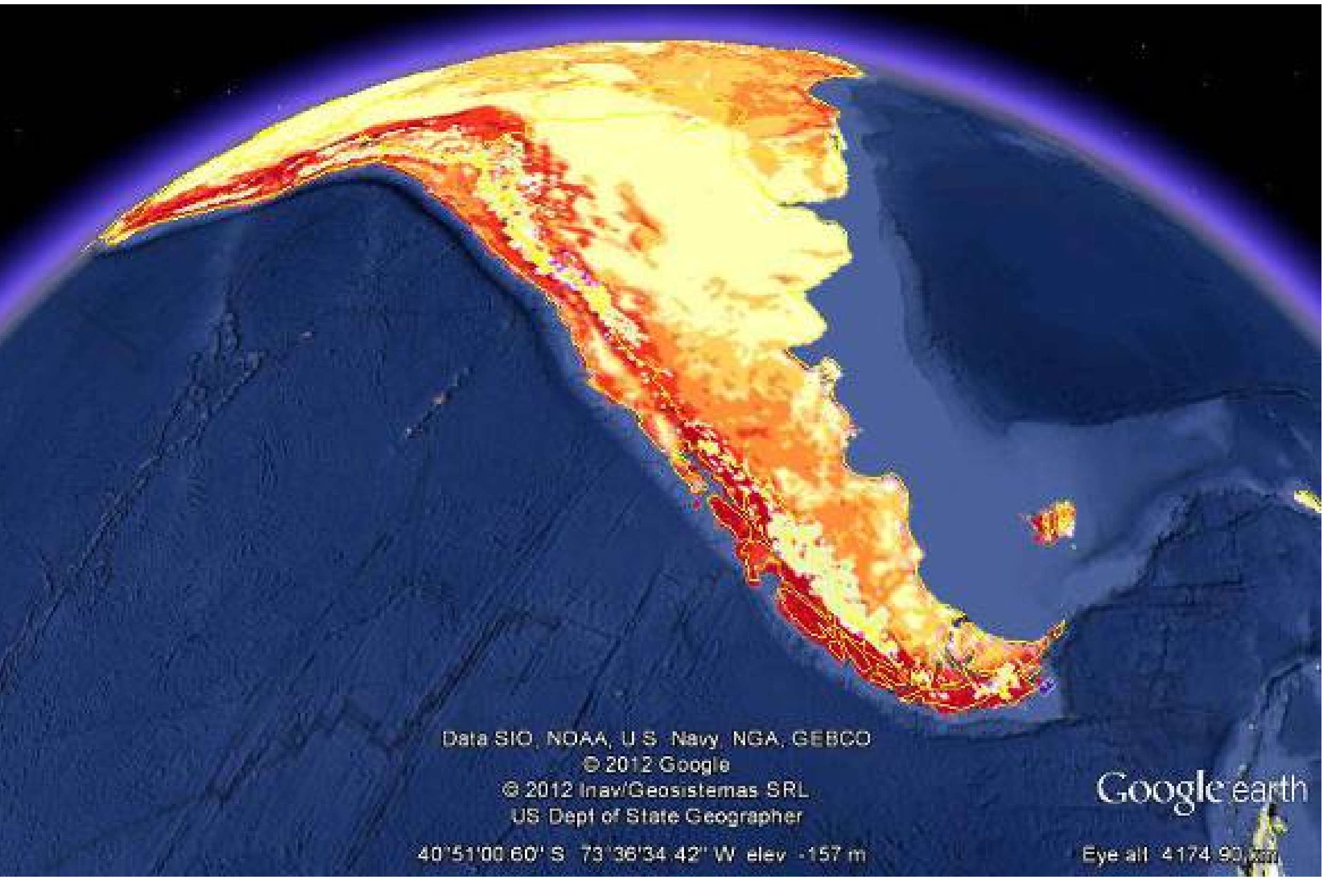
Article 7 mandates environmental impact studies for activities that are carried out in periglacial environment areas.

Article 15, on transitory dispositions, also includes the periglacial environment relative to the possible moving or design modification of activities that could affect the periglacial environment.

Where is the Periglacial Environment in Argentina?

According to Corte (1983, pp. 157-158), the presence of frozen grounds in Argentina is divided into 6 distinct zones:

Zona 1: Latitude 64˚ South, as for example, the Marambio or Cockburn islands in Antarctica;
Zona 2: Latitude 60˚ South, as for example, Signy/Coronation islands;
Zona 3: Ushuaia, Tierra del Fuego as of 900 meters above sea level;
Zona 4: Patagonian mountains, in Río Negro, Bariloche … as of 2, 200 m
Zona 5: Mendoza as of 3, 200 m and up to 4,800 m
(the regular freezing and unfreezing regular layer is between 2,400 and 3,200m)
(below 2,400 there may be irregular freezing/unfreezing)
Zona 6: The Puna in Salta as of 4,000 meters
(the regular freezing and unfreezing layer is between 3,000 and 4,000 m)
(between 2,000m and 3,000m there may be irregular freezing/unfreezing)



The question we ask when trying to implement the National Glacier Law and in order protect the periglacial environment, is if we can determine, without actually making a sight visit as would a glaciologist studying the environment, if there or aren't frozen grounds at a given site containing water, which would imply that they are protected by law. If we can conclude with some precision the probable presence of frozen grounds at a given site, and if these grounds contain ice, or if they are contributing water to the ecosystem, then we can insist that studies be carried out to eliminate any doubt over the eventual impacts they may suffer and in this way, guarantee the protection of the resource.

There are various methods available utilized by experts that anyone can employ with minimal training and minimal knowledge of the technical elements and of the available techniques that are freely and publicly accessible at no financial cost. Of course, the last step, the definitive verification of the information obtained should be left to the experts. However, this does not hinder the non-expert from making valid and educated recommendations to guide public policy decisions, in an effort to help apply the law. We *can* see glaciers, we *can* see rock glaciers and we *can* see that the State is not complying with its obligation to protect glaciers and rock glaciers. We should call on the state to comply with the law, and that the necessary studies and inventories be carried out in order that we official establish the existence of the glaciers as well as their formal protection.

According to the work by Stephan Gruber, whose global permafrost model is described below, there are some 30,000 km² of frozen grounds in Argentina (Gruber, 2011 p.231). We recall that the periglacial environment is a zone defined by thermal and geographic characteristics, situated in between the glaciated zone and the forest line. The edges of this zone may intermix, but essentially, these are the limits of the periglacial environment.

Method 1: Registration by Identifying Rock Glaciers

There are two methods which experts use to identify periglacial environments, which anyone can use, at least in the initial stages of an inventory: *the method by registering rock glaciers*, which are visible via satellite imagery which anyone can access on *Google earth*, and the *automated model method* which analyzes satellite imagery and temperature readings of the air and elevation readings. Let's examine each and carry out some exercises to use each method.

A. Corte provides us with several key points to help us identify where the periglacial environment is. Referring to the Central Andes, he says:

> "For the dry Central Andes, between 20˚ - 35˚ L.S, it's possible to draw a clear limit between the geo-cryogenic and parageocryogenic areas. In these regions the lower geo-cryogenic limit coincides with the lower limit of the sporadic mountain permafrost, which is defined as the lower limit of the active rock glaciers." (Corte 1983, p.265)
>
> The lower limit of the rock glaciers has been used to establish the lower limit of mountain permafrost, … rock glaciers are indicators of permafrost near 0˚C at their lower areas and cold permafrost at their higher elevation." (Corte 1983, p. 124) (unofficial translation)

In simple terms, find the low points of the rock glaciers, and that's where the periglacial environment begins. This is a relatively simple task, since rock glaciers have very typical characteristics at their lower ends, such as a particularly shaped tongue which is easily identifiable, as well as an abrupt ending cut sharply at a 30-40˚ angle. Below we share 3 images of active rock glaciers in different areas of North West Argentina and the Cuyo.

These are very easily identifiable for a non-expert! The arrows below show the low points where frozen grounds begin.

Dario Trombotto, in more recent publications, reaffirms this method, "rock glacier activity permits the identification of the presence of permafrost in Andean subsoil." (Trombotto, 2009, unofficial translation).

Rock Glacier in Salta Province
25 00 33.70 S, 66 21 19.14 W

Rock Glacier - Catamarca Province
27 18 22.94 s, 66 10 14.89 W

Rock Glacier - San Juan
30 04 10.20 S, 69 56 10.35 W

Low points of Active Rock Glaciers denote where Periglacial Environment Begins

If we extend this example to a specific area, for example, in the vecinity of a mining project where we would like to know if there is permafrost present (an element of the periglacial environment), what we need to do is to register all of the visible rock glaciers, register their lowest elevation points. That's where the periglacial environment will be located.

We should take note that periglacial environments may vary from one micro area to another. It is possible that a low point reference may change from one mountain slope to another. That is, the lowest point of a single rock glacier, may not be the reference for the entire area. It could be that there will only be periglacial environment in the vicinity of that rock glacier.

Evidently, this is an exercise and method with much margin of error, in part because there may also be periglacial environment that is not visible by satellite image, or rock glaciers that do not unite the necessary characteristics (such as a tongue ending cut sharply) to carry out the exercise. Also, inactive rock glaciers may confuse us since there may be a rock glacier, but no longer permanently frozen grounds. It may be a site where a rock glacier is on route to extinction. But in general, the generic particularities *do* give us a sense of what the general situation may be like in a given area, and without the need for a site visit, we can draw many useful conclusions with which we can later commend more specific ground studies. We must then carry out those studies with much more precision to determine where the periglacial environment is, what it is like, etc.

Example:

We can take the case of the mining project Los Azules (McEwen Mining) in the province of San Juan Argentina. The project is perfectly visible via *Google earth*, at approximately:

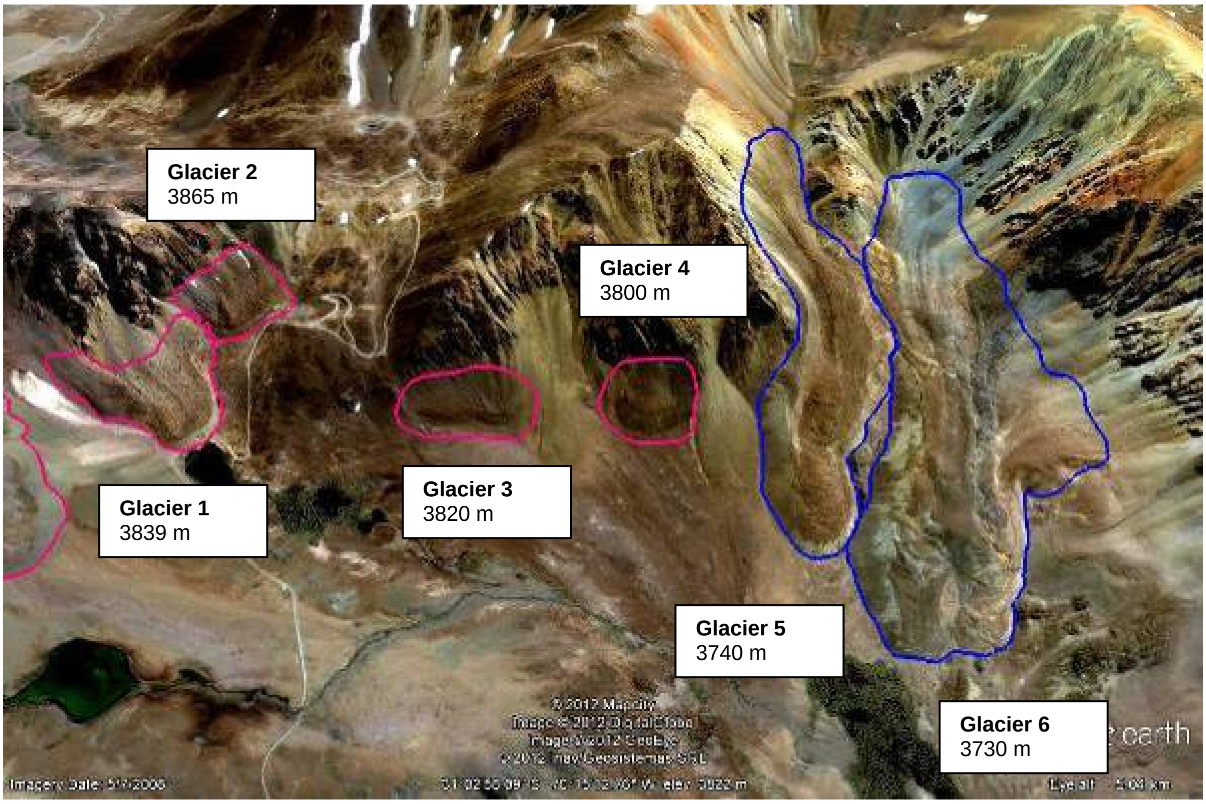
31°06'09.88" S 70°13'12.44" W

In this image we see 6 rock glaciers, identified in the image as colored polygons. We see that they have the typical abrupt cut and a tongue shaped ending just as we saw above.

We can see these rock glaciers via *Google earth* at: 31°02'58.09" S, 70°15'12.76" W. From left to right we register the heights at the lowest points:

Rock Glacier (1): 3,830 m
Rock Glacier (2): 3,865 m
Rock Glacier (3): 3,820 m
Rock Glacier (4): 3,800 m
Rock Glacier (5): 3,740 m
Rock Glacier (6): 3,730 m

In this particular micro-zone of the Los Azules project, we see that rock glaciers begin at 3,730 meters. We can infer by this measurement that so does the periglacial environment, at least in any area near these rock glaciers we might find frozen grounds as of 3,730 meters. So if we are a public official, and we are attempting to ensure compliance with the glacier law, and we are controlling McEwen's project, we should ensure that in addition to glacier impact studies for Los Azules, McEwen should be carrying out periglacial environment impact studies for all activity in areas above 3,730 meters in the vicinity of these glaciers.



Continuing with the same example, of Los Azules, we can carry out a much broader anaysis by inventorying all of the rock glaciers in the area of the project. This exercise gives us the following result. (see image to the left).

Our glacier inventory at Los Azules revealed that there are at least 226 glaciers in the project area, or in the vicinity of the concession area.

Where is the periglacial environment at Los Azules?

Our registered low point elevations for all of these rock glaciers was 3,540 meters, corresponding to a single talus glacier located at::

31°05'41.28" S 70°18'57.70" W

This implies that at least near this glacier, we might be in a periglacial environment. Any altitude above 3,540 meters, should be considered for possible presence of frozen grounds, as it is highly probable that at this elevation at Los Azules, we might find periglacial environments.

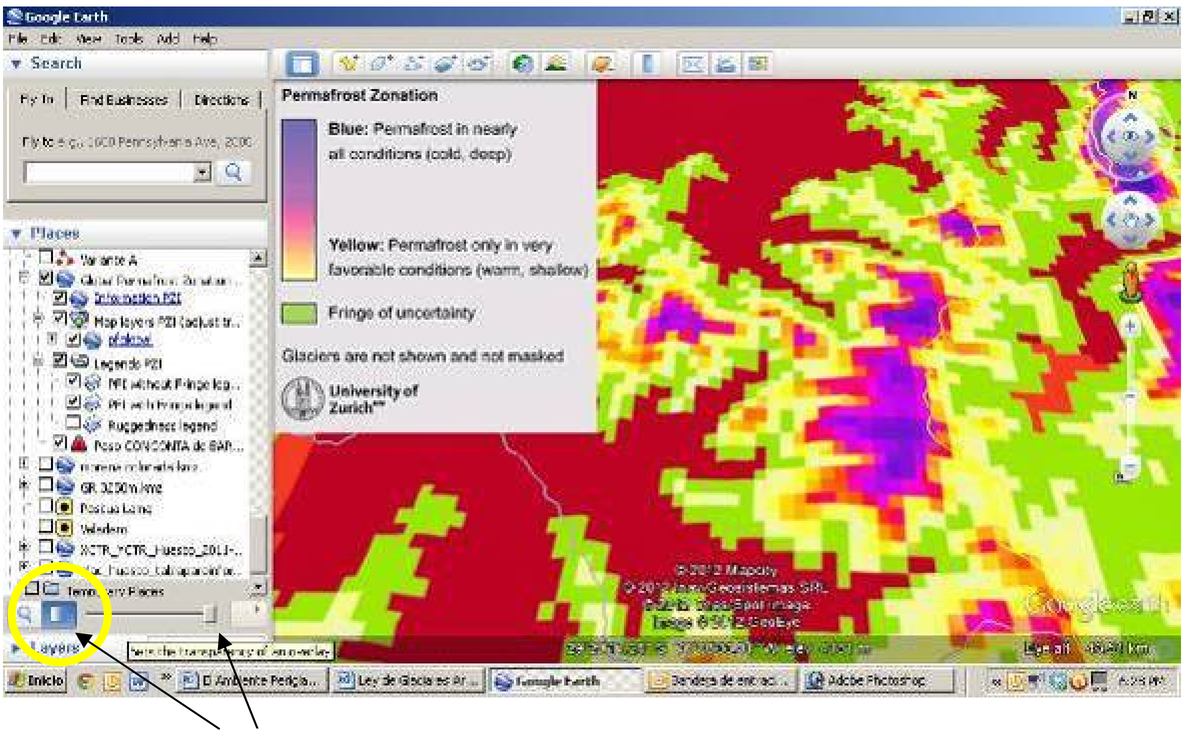
Method 2: Method by Global Permafrost Mapping

The University of Zurich, Switzerland, has developed a scientific based model, that processes existing reliable data on elevation and air temperature for the entire planet, and determines the probability of the presence of frozen grounds for any given area of the entire planet. This is, in essence, a global permafrost map. This map can be obtained easily and at no cost, simply with an Internet connection. The reader can download this global permafrost map at:

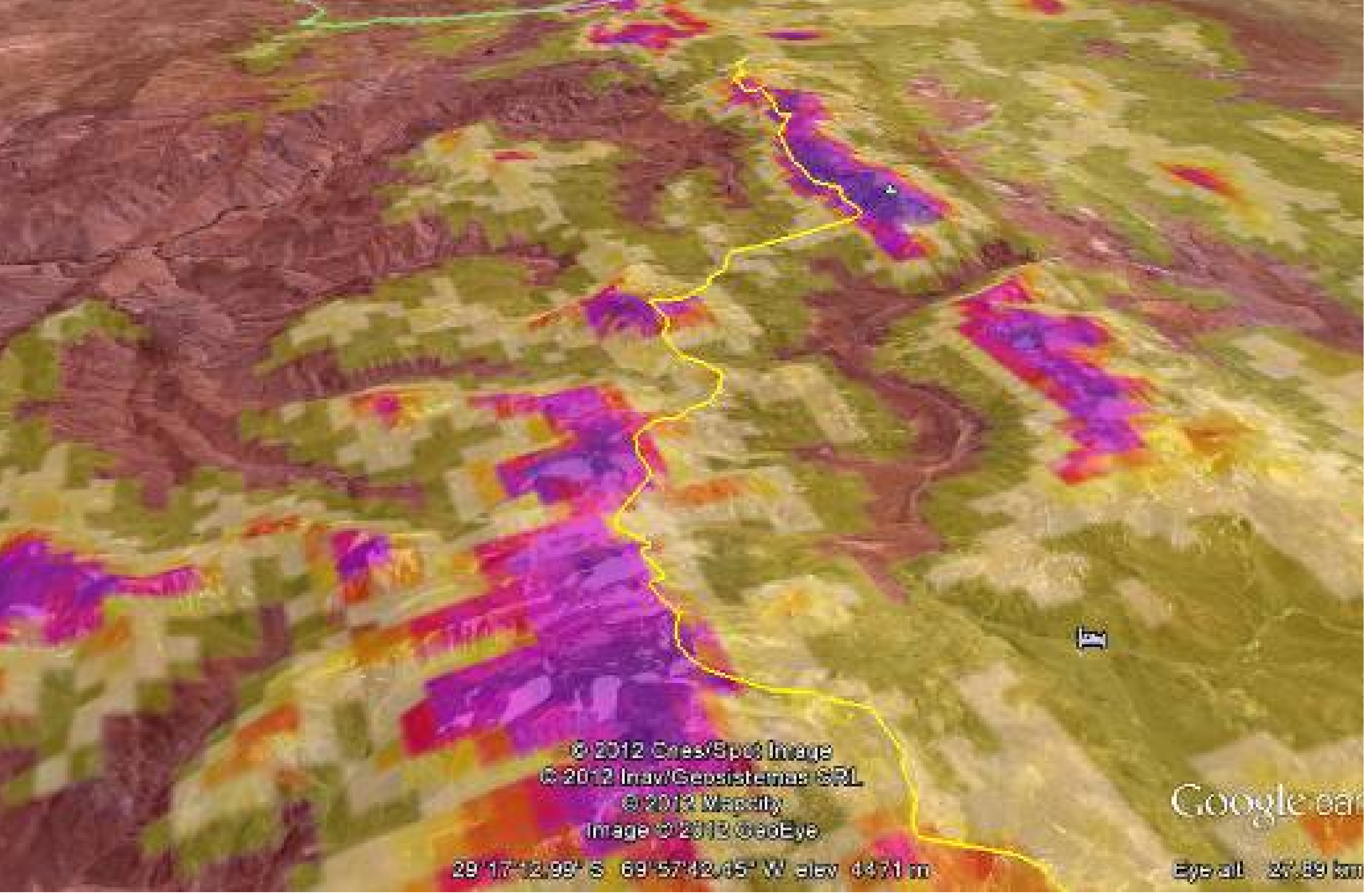
http://www.geo.uzh.ch/microsite/cryodata/pf_global/GlobalPermafrostZonationIndexMap.kmz

The file has the extensión ".kmz" which is a file that can be seen on *Google earth.* It's very practical and simple to use. Simply download the file, unzip it, and open it in *Google earth*. With this file loaded on *Google earth,* any place visited on the globe, will automatically load the permafrost map, and will superimpose the permafrost identification over the normal *Google earth* image.

It may take a few moments to load the image the first time. With *Google earth* open, at any location with frozen grounds, you will see an image such as the one below, which corresponds to the mining project Pascua Lama by Barrick Gold. In the pane on the left side of the screen, several files appear, some of which correspond to the permafrost map, legends, and options. The viewer can tick and untick boxes at will, such as removing "ruggedness" of terrain, which allow for better viewing of the normal outlying land images, or remove legends by untick each accordingly. In the image we see purple and violet colored zones, which are probably permafrost areas. Our rock glacier inventories (which would denote permafrost) for the Famatina mountains, Aconquija mountains, and mountains in Jujuy, Salta, and San Juan, confirm the effectiveness of the permafrost model to locate periglacial environments.



These buttons/options allow for fading permafrost images



Pascua Lama Project (Barrick Gold): Fading tool on *Google earth* permits making permafrost mapping images transparent

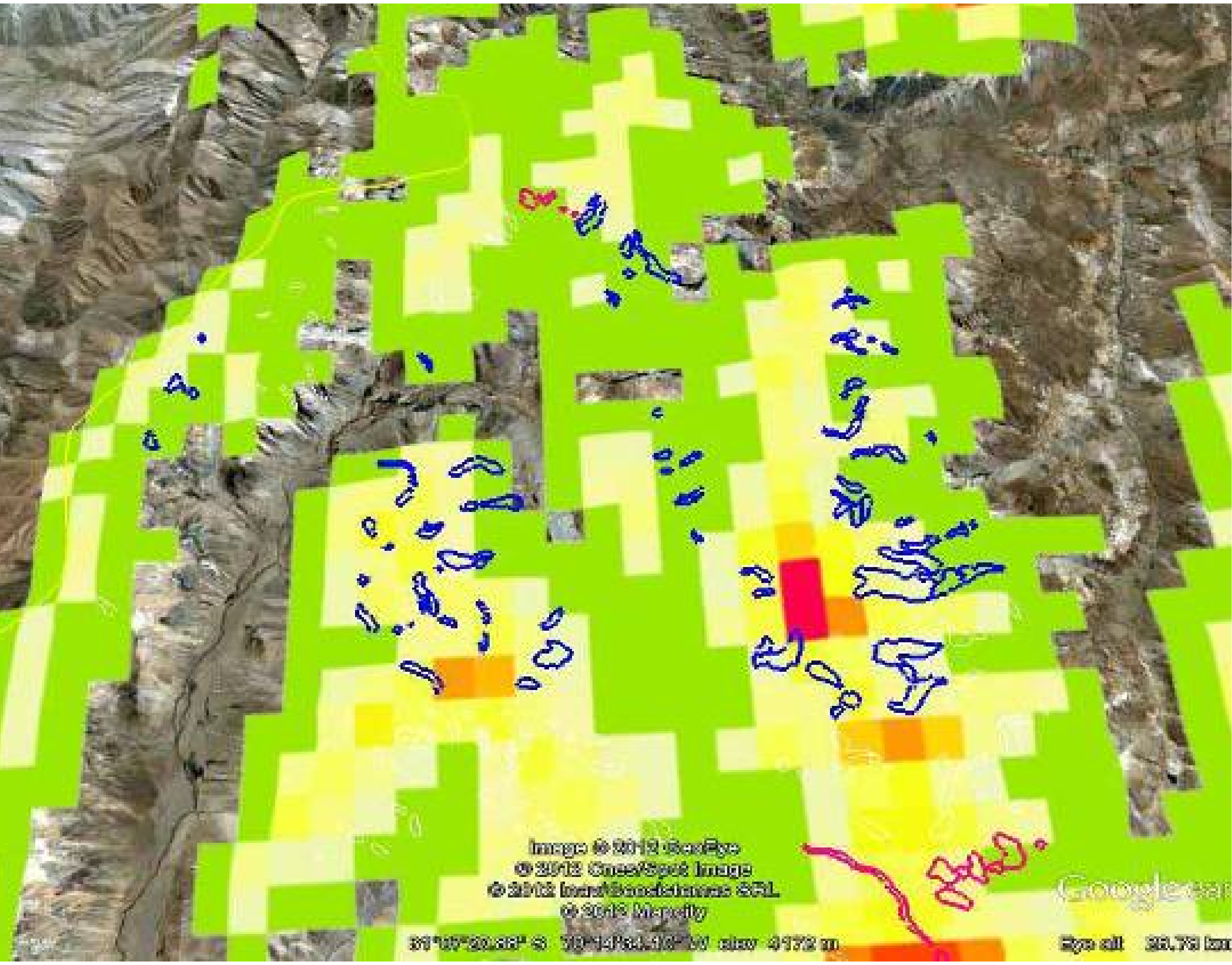
Also on the left panel on *Google earth*, you can select to activate the image fader, to see the permafrost information just loaded in superimposed fashion with the normal *Google earth* image below. To activate this tool, click on the small screen icon that appears in the lower left corner of the left pane (see yellow circle in the image on the previous page).

It would be interesting to compare the two techniques (the Corte method—or method 1) by identification of rock glaciers, with the University of Zurich permafrost mapping model—method 2. If we go back to the prior example, Los Azules, and the rock glacier that we had inventoried as the lowest of the project area, the result of the comparison is surprisingly precise. Below we see the glacier that we has located, that should be, according to method 1, at the lowest end of the permafrost zone. We can go to this site at: ar en:

31°05'41.28" S 70°18'57.70" W

In effect, the Zurich map places us exactly at the edge of the "the area of uncertainty" for frozen grounds. This is precisely what we had supposed. This is the lowest point of the probable periglacial environment.

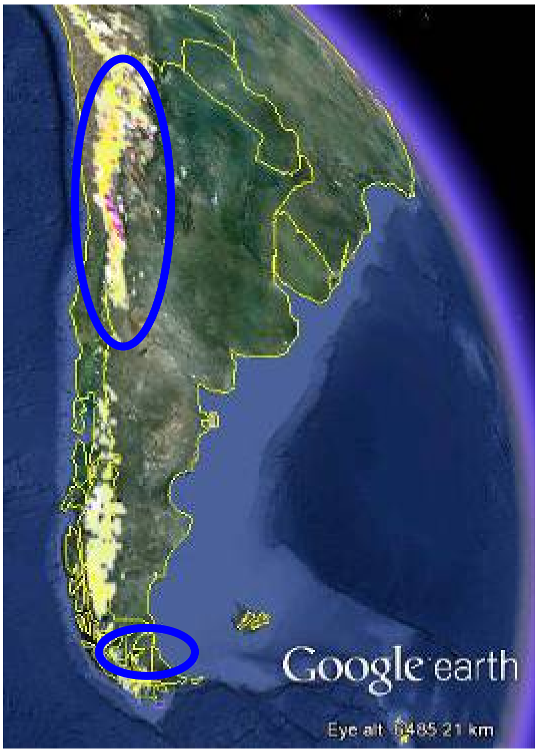
Even more surprisingly, when we compare the entire project area, with all of the rock glaciers that we mapped in our inventory, and we superimpose the images with the Zurich model, we see that the coincidence is almost perfect. The glaciers are precisely where the global mapping model predicted they should be. There are practically no rock glaciers outside the yellow and green zones of the model, only a few select low points of a few rock glaciers.



Near perfect coincidence between the inference model for finding permafrost with the Zurich permafrost model for the Los Azules (McEwen Mining) project.

Argentina’s Territory and the Periglacial Environment

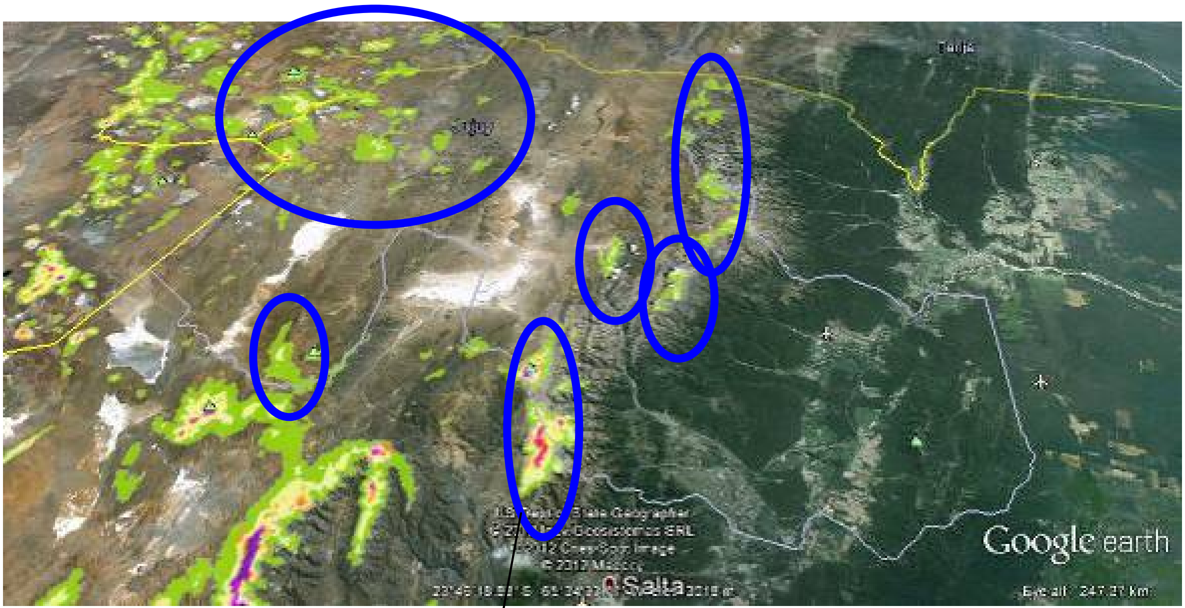
Lets see hence the principle area of Argentina where we find frozen grounds (permafrost). We should be clear, the Zurich University Global Permafrost Mapping is approximate, and we cannot draw definitive conclusions from this information, but without a doubt, it is an excellent indicator to help us determine with a great degree of probability, were we can find glaciers, debris-covered glaciers, rock glaciers, and frozen grounds. We at CEDHA use this mapping to inform our own glacier inventory exercises, enormously facilitating our task. We start our inventories and registering of glaciers and rock glaciers, by first going to the areas cited in the Zurich model as the coldest, and we can be sure that there, we wont be far from the glaciers!



We can see from the image on the left, that the permafrost areas (frozen grounds) are practically all along the Andes Mountains, and principally in the Central Andes corresponding to the provinces of Jujuy, Salta, Catamarca, La Rioja, San Juan, Mendoza and more to South, Santa Cruz. This is noteworthy, and possibly contrary to what we might have guessed, … there is more permafrost in the Central Andes than in the South of Argentina (not counting Antarctica).

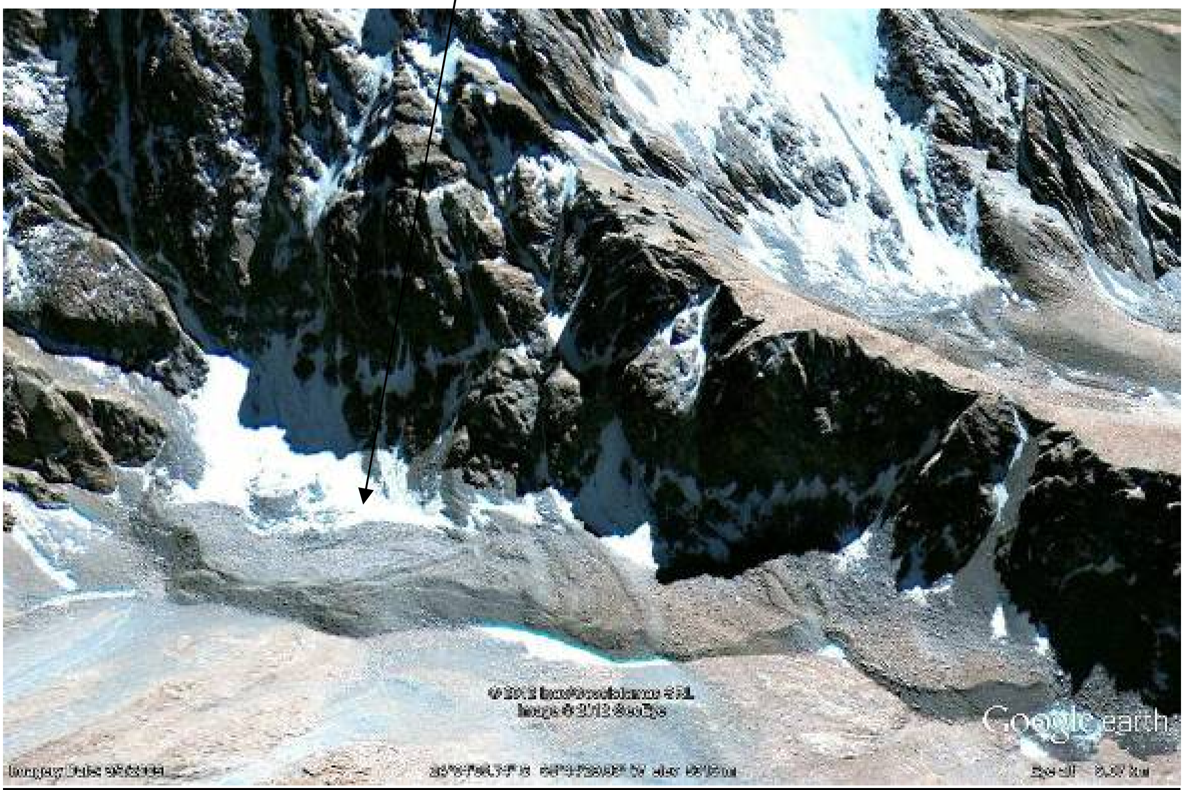
We also see that there are frozen grounds in other mountain ranges in Argentina, including Famatina (La Rioja), the Aconquija and Calchaquí Ranges, and in the Cerro Laguna Brava y Cogalan (Catamarca and Tucumán), and in the border area between Salta and Jujuy provinces.

Jujuy



In Jujuy province, we see various periglacial environment areas, and more specifically, frozen grounds, mostly in the high mountains (above 4,000 meters) and in the border areas with the province of Salta as well as in the mountains near the Bolivian border. In each of these areas we find rock glaciers as those in the images that we show below.

Active Rock Glaciers and Periglacial Environment in Jujuy. See at: 24°04'10.88" S 65°44'31.20" W

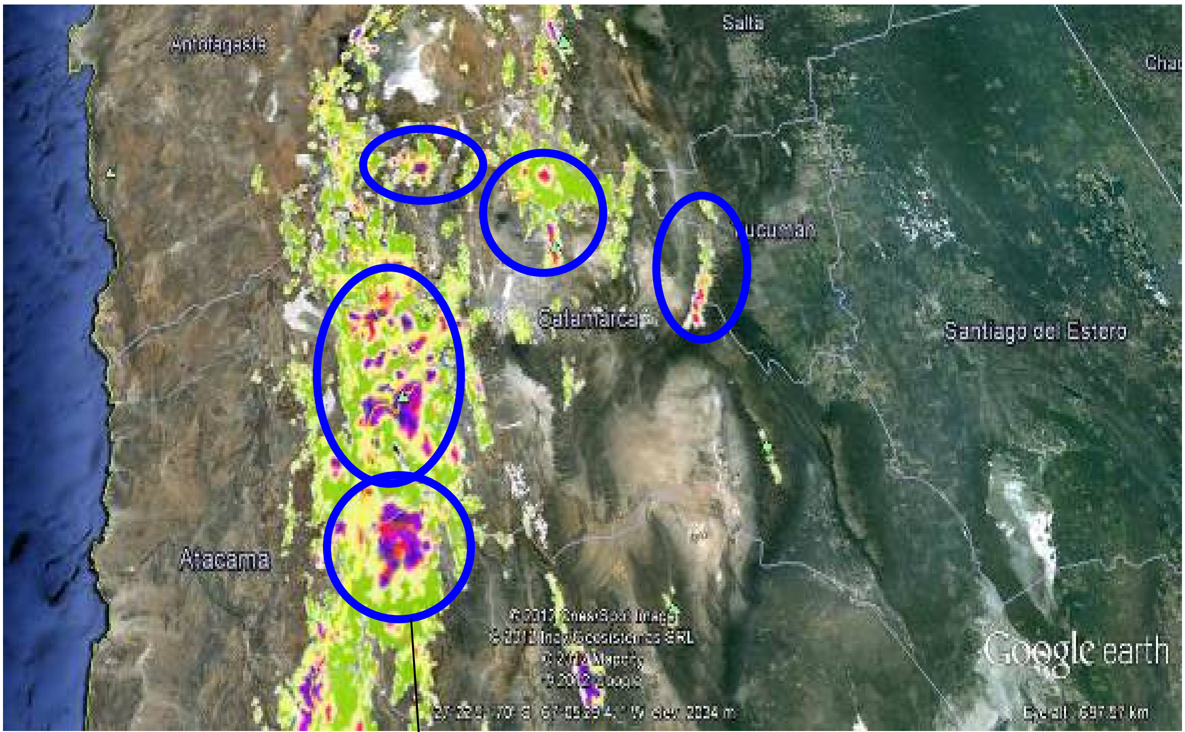


Salta

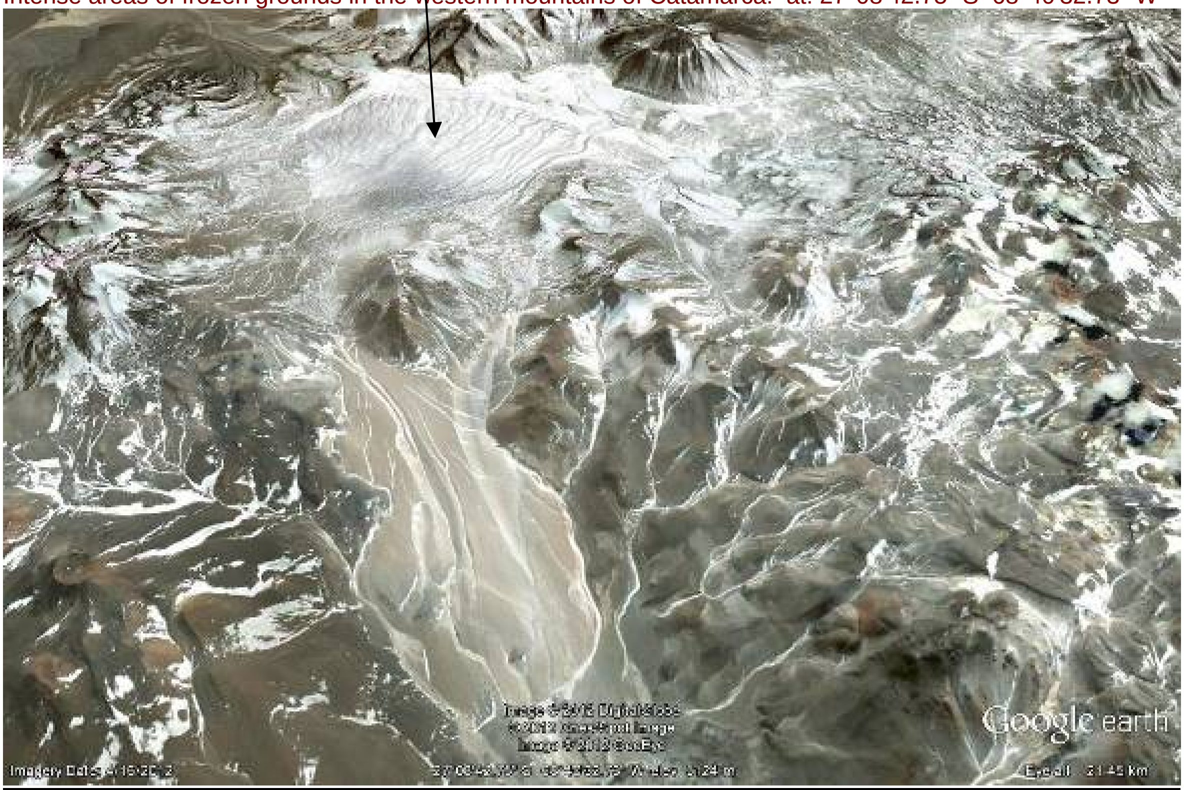
The areas with most frozen ground is not in the western Andes, but rather in the Cachi mountains, at: 24°55'13.12" S 66°23'13.82" W

2km of magnificent active rock glaciers in frozen grounds of Salta. See at: 24°45'34.84" S 66°22'37.41" W

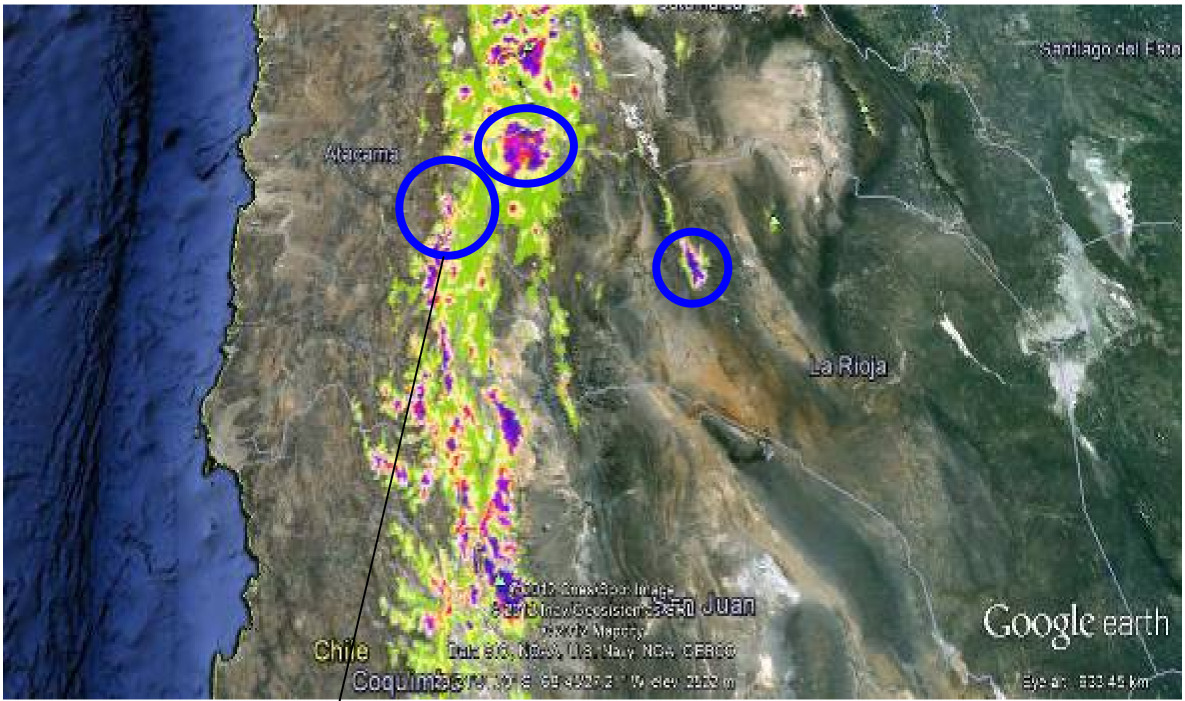
Catamarca



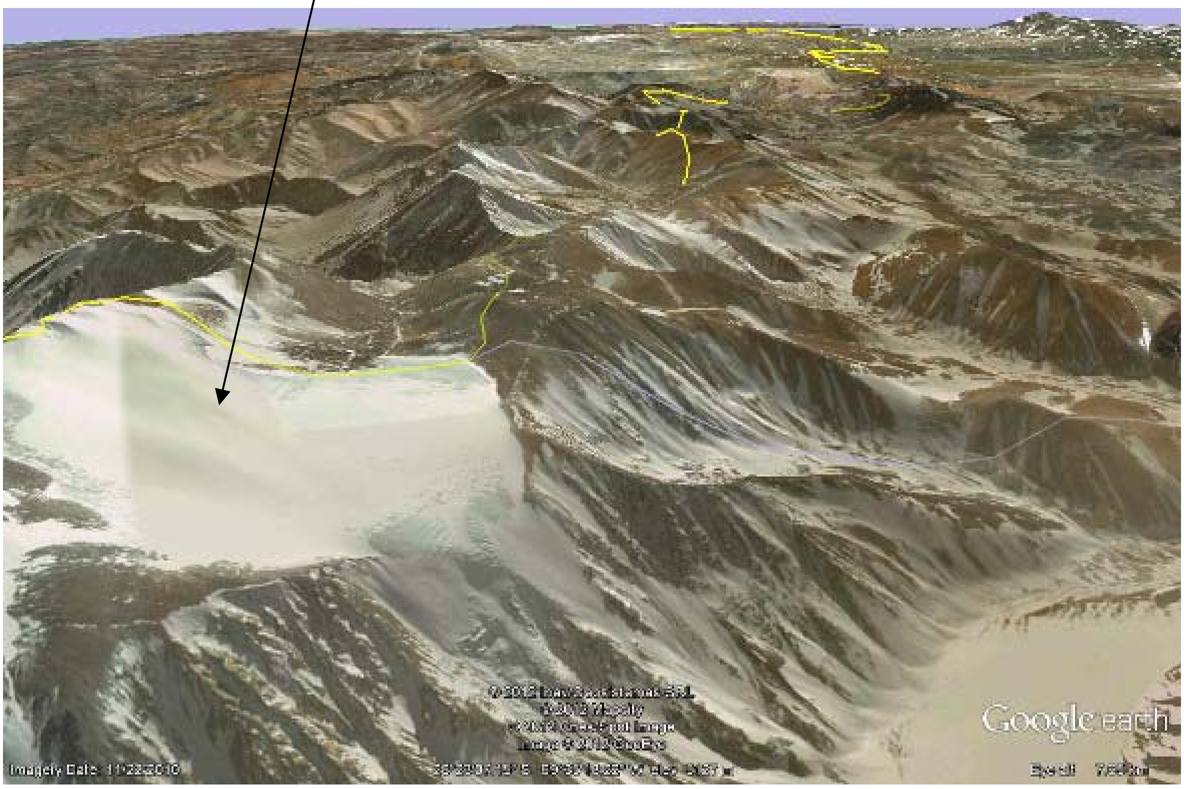
Intense areas of frozen grounds in the western mountains of Catamarca: at: 27°08'42.75" S 68°40'32.73" W



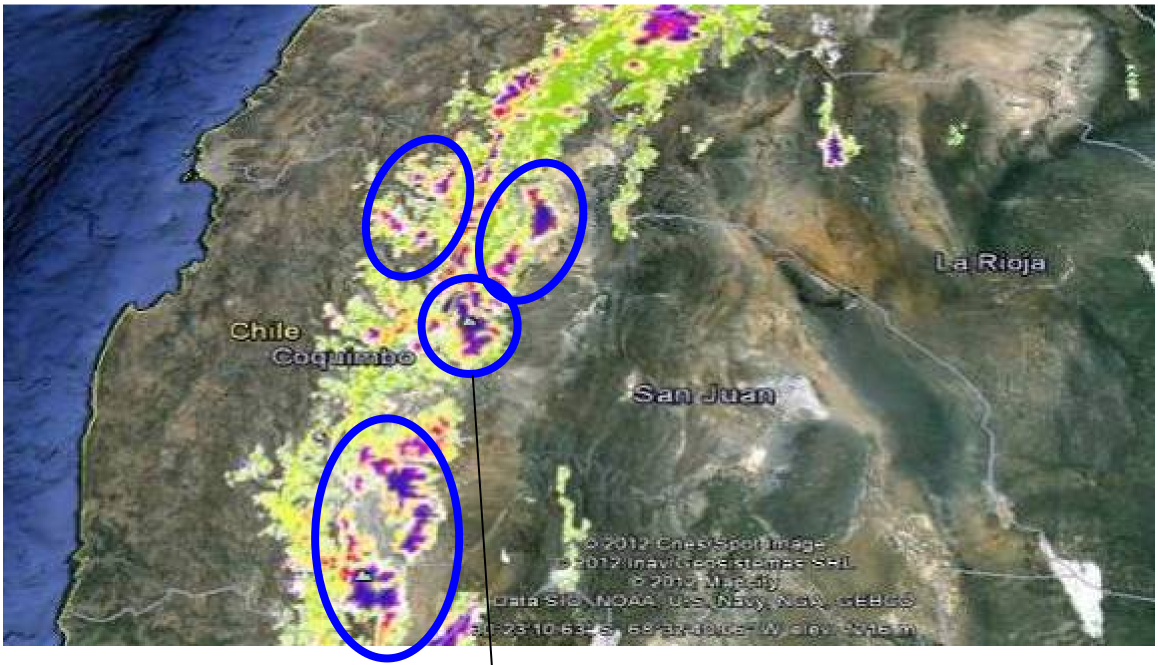
La Rioja



Area surrounding the El Potro Glacier, 28°23'12.53" S 69°35'37.35" W, -- extensive frozen grounds in La Rioja.

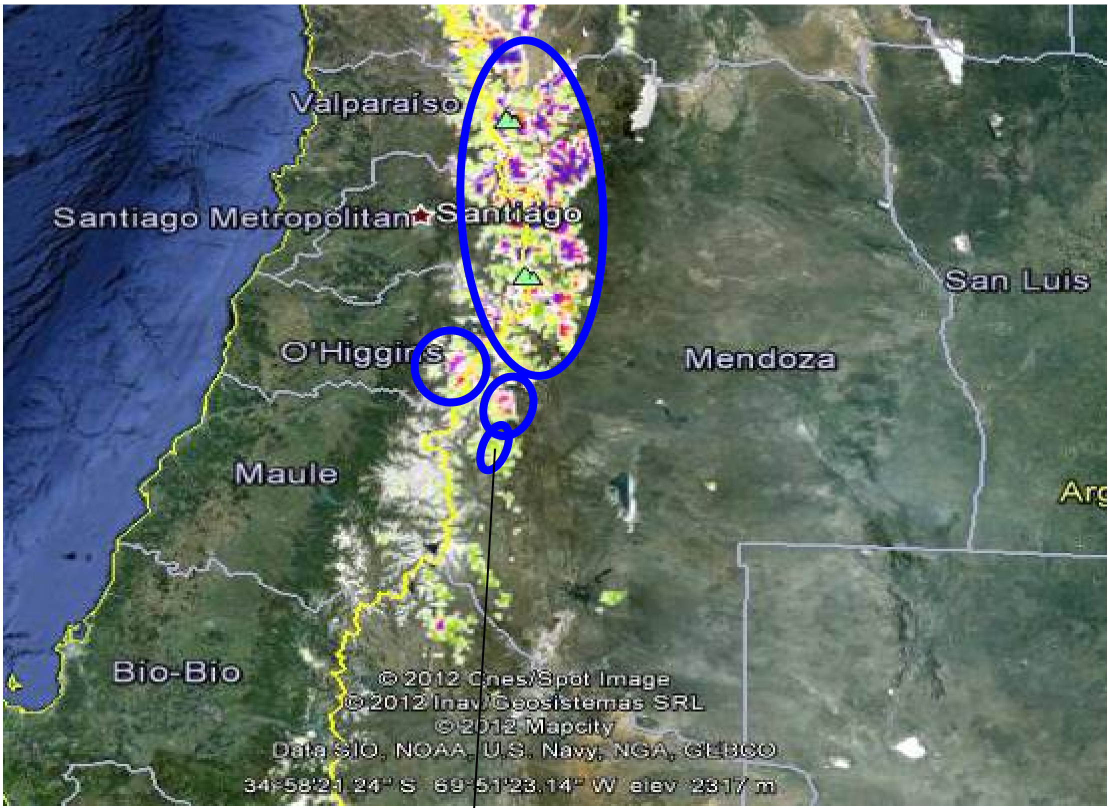


San Juan

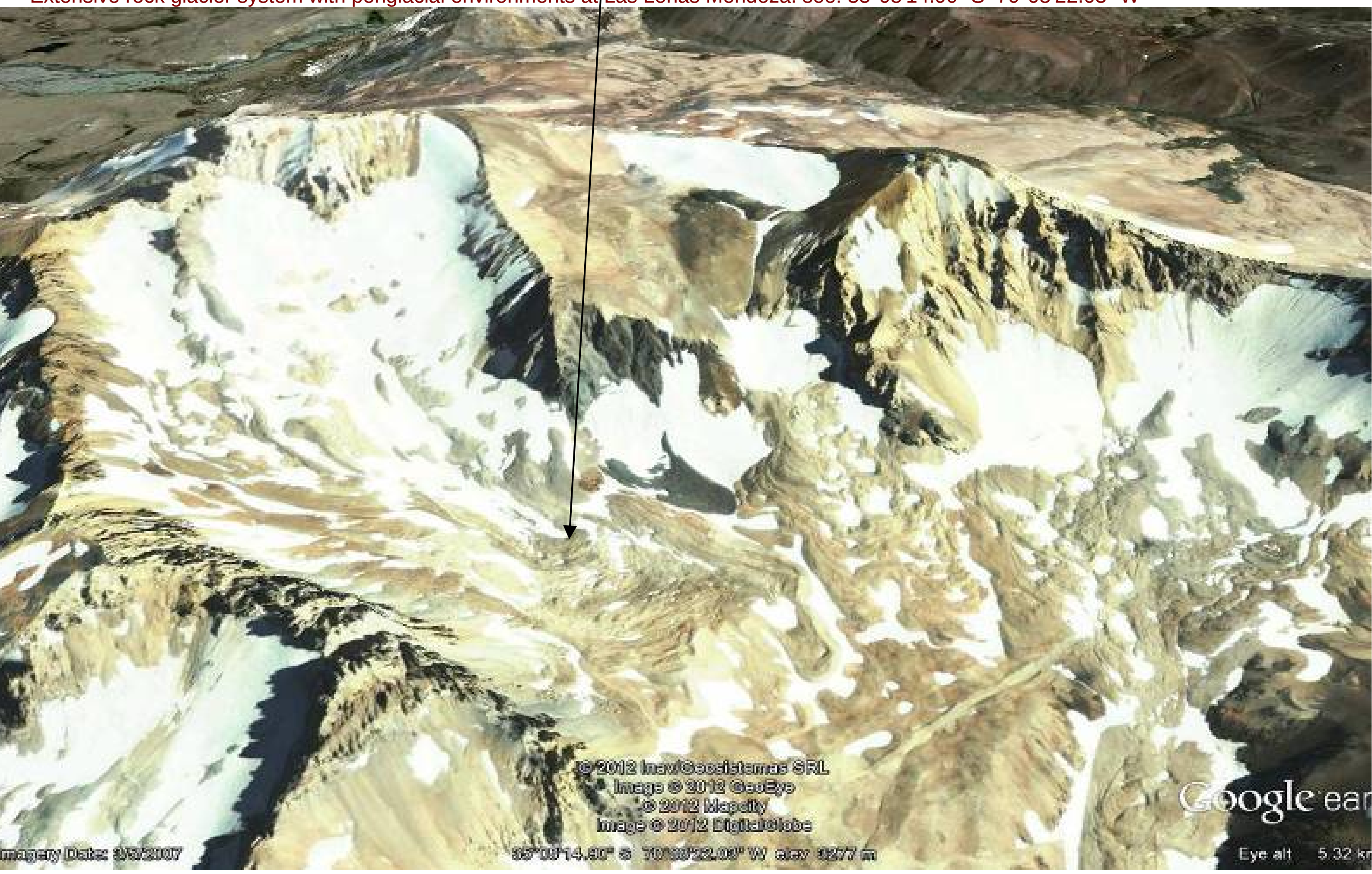


The Pircas Negra Glacier, in San Juan, is surrounded by frozen grounds. Photo: Osvaldo Garcia; see at: 30°23'27.87" S 69°47'32.04" W

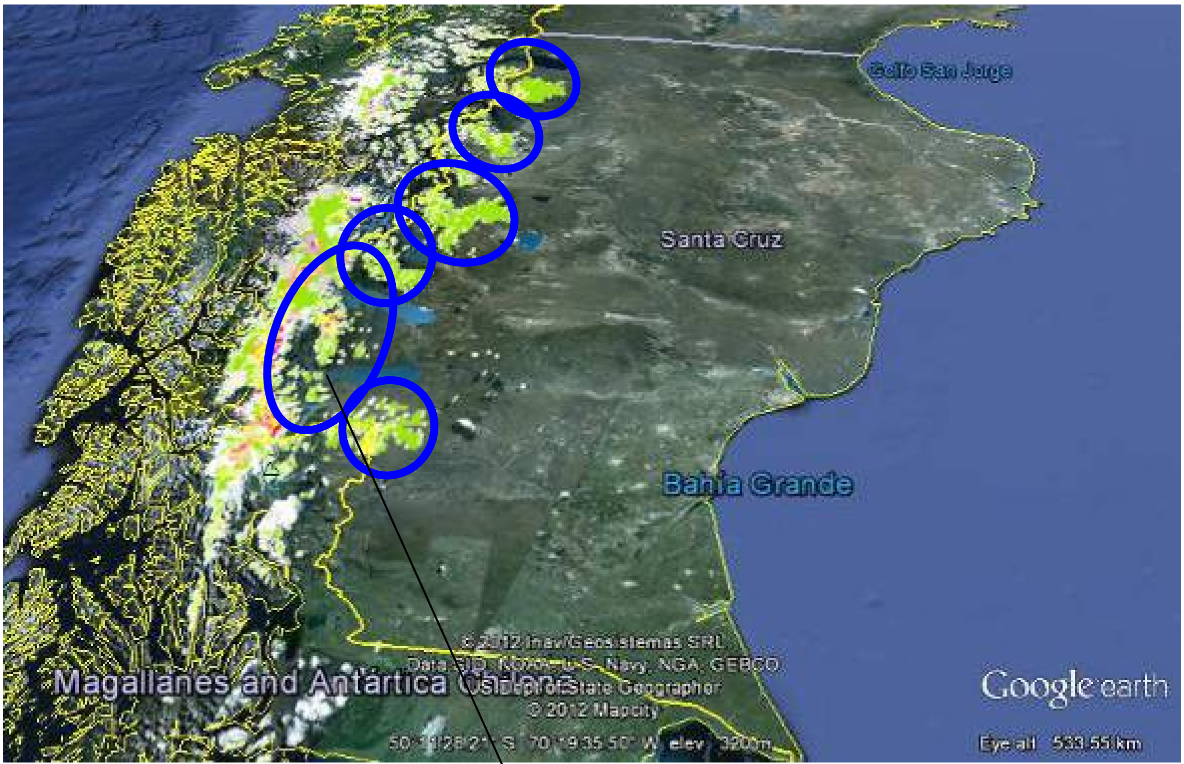
Mendoza

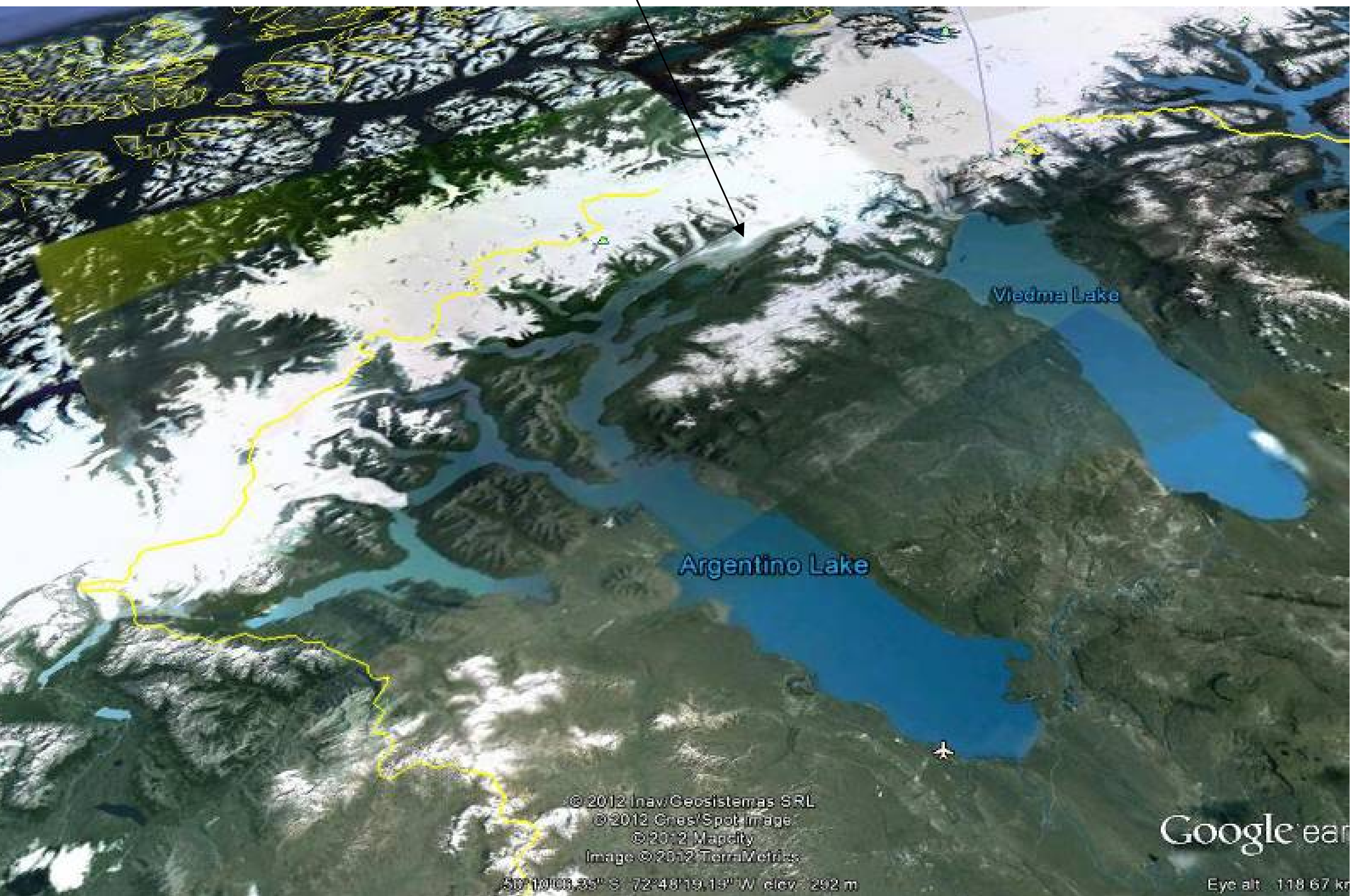


Extensive rock glacier system with periglacial environments at Las Leñas Mendoza. see: 35°08'14.90" S 70°08'22.03" W

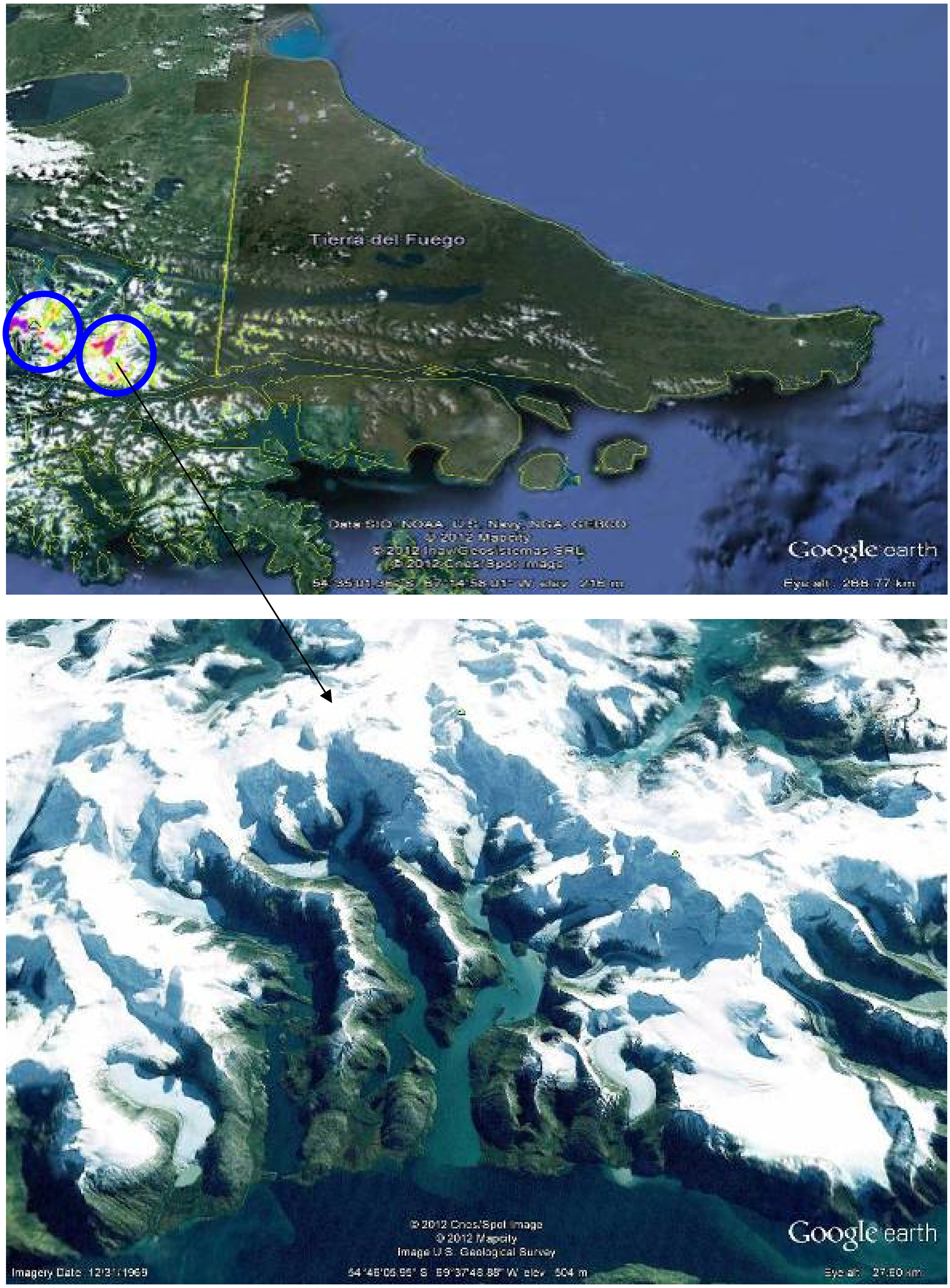


Santa Cruz


Golfo San Jorge
Santa Cruz
Bahia Grande
Magallanes and Antártica Chilena
Google earth


Viedma Lake
Argentino Lake
© 2012 Inav/Geosistemas SRL
© 2012 Cnes/Spot Image
© 2012 Mapcity
Image © 2012 TerraMetrics

Tierra del Fuego



Periglacial Environments and Mining in Argentina

There is mining where there is periglacial environment.
There is mining where there are frozen grounds.
There is mining where there are rock glaciers.
There is mining where there are debris-covered glaciers.
There is mining where there are uncovered glaciers.

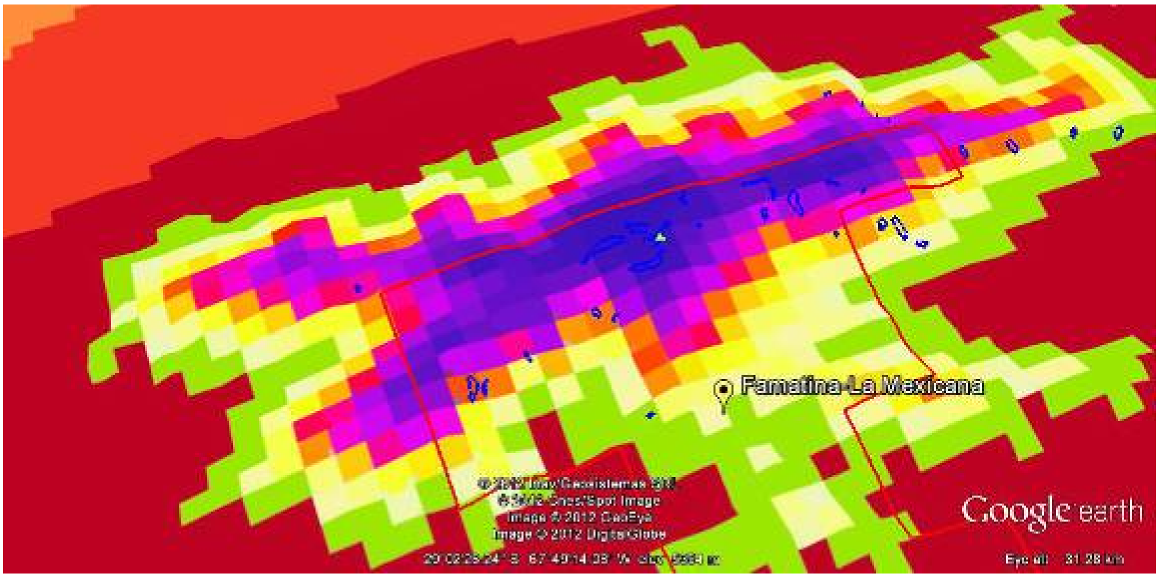
This is not speculation. This is not our opinion. There is no doubt of these affirmations. At present, e can very easily verify this relationship with publicly available tools such as *Google earth,* without needing to go to the site in question. There is legally protected ice where there are mining projects underway. It is not true what some provincial and national authorities have said, denying this reality. A great part of the mining exploration now underway in the Central Andes, in provinces such as san Juan, and in some parts of La Rioja, is taking place in periglacial environments. In many of these cases, we can already see impacts of mining to these legally protected resources. There are numerous documented cases, with scientific information to sustain the findings, with geologists that attest to them, and even from the consulting firms hired by the mining companies, that sustain these affirmations, as for example in projects such as Los Azules (McEwen Mining), El Pachón (Xstrata Copper), Filo Colorado (Xstrata Copper), El Altar (Stillwater), Del Carmen (Malbex), Veladero y Pascua Lama (Barrick Gold), and many more.

The Global Permafrost Map by the University of Zurich is an excellent tool to shed light on the probability of frozen grounds where mining activity is underway. Knowing where the mining project is located, one can easily view the site on *Google earth,* load the permafrost map and in a few seconds, know if we are potentially in a periglacial environment. How sure can we be of this correlation?

If we compare that rock glacier inventories we've carried out with *Google earth* images, with the information we obtain from the Zurich map, the coincidence is strongly revealing. Let's take the area around Famatina (*ex Barrick Gold*, now Osisko) in La Rioja (the red polygon in the image is the concession area) as an example. This site is visible at: 29°01'19.95" S 67°49'42.93" W. Entering via *Google earth*, the reader can verify the analysis for herself.

In the following image, we see the uncovered glaciers and rock glaciers that we plotted **before** having access the Zurich Global Permafrost Mapping. We see the glaciers as blue polygons.

This glacier inventory was carried out using Method 1, analyzing satellite images where we can clearly see the presence of cryoforms (rock glaciers). According to Corte's indications, we should assume that if there are rock glaciers, we're in a permafrost zone (rock glaciers are permafrost), and this implies that there is periglacial environment present (since rock glaciers are an element of the periglacial environment). If we compare this to what is revealed by the University of Zurich Permafrost Mapping tool, we should find that the majority of the rock glaciers are in purple or blue zones, in yellows zones (which are where permafrost exists in favorable conditions), or in green zones (which is the zone of uncertainty). In the following image, loaded on *Google earth,* we see the Zurich mapping results.



We see that the great majority of the inventoried glaciers are effectively within the blue/purple zones or in the yellow/green zones, where we expected them to be and that the ones that are in the green zones, are still in areas where there may be frozen grounds. None of these glaciers are outside of the probability zones. The Zurich map hence, helped us determine *ex-ante* where we might find uncovered glaciers or rock glaciers. It does not tell us exactly where they are, but it reveals the area where we should look.

Again, this analysis *is not definitive*, but rather *indicative of probabilities.* The necessary studies should be carried out to determine specific characteristics and verify findings. The tool is extremely useful for both companies operating in glaciers areas, or for the State which needs to control companies in the region, or for the justice system which should oblige actors to carry out their responsibilities and also to determine which mining projects should carry out glacier and periglacial environment studies. The law obligates that these studies be carried out within 180 days of the promulgation of the law, in cases where there may be impacts to glaciers or periglacial environments. Unfortunately, we have no official information indicating that these studies are actually being carried out. With the tool offered by the University of Zurich there is no excuse to delay these priority inventories any further.

Let's ses a few mining projects where there is a perfect coincidence between location of the mining project and the permafrost map.

For all of these mining projects, the companies should definitely be:

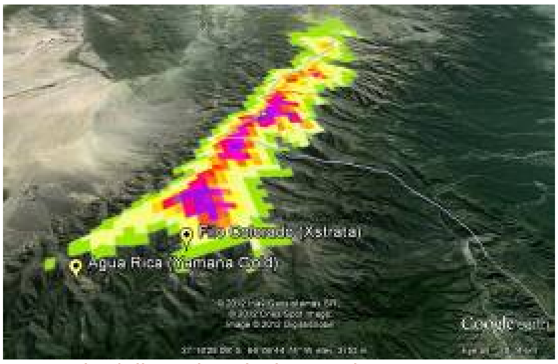
- contacting specialists to carry out glacier and periglacial environment inventories;
- carrying out glacier and periglacial environment inventories in their project area;
- measuring/determining hydro-value of the glaciers and periglacial environments;
- studying past, present and any future impact to glaciers and periglacial environments in the project area;
- establishing a glacier protection policy and the management systems necessary to carry out the policy;
- halting all exploration and extractive activity until it can be confirmed that they are not impacting glaciers or periglacial environment;

The States that have mining projects in their jurisdiction in glacier areas should:

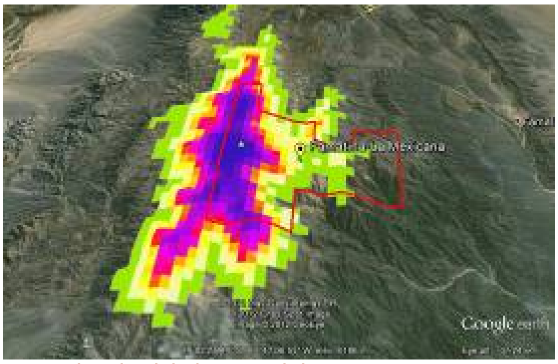
- ensure as soon as possible that glacier and periglacial environment priority inventories are carried out;
- demand that mining companies operating in glacier and periglacial environment areas produce pertinent studies to determine past, present or future impacts of activities to these resources;
- assure they obtain the necessary information on hydraulic value of periglacial environments;
- suspend any activity of any extractive industry (including exploration activity) until impacts can be properly gauged;

Mining Projects in Periglacial Environment Areas

We see below some projects that show coincidence with frozen ground areas (which are part of the periglacial environment). We should recall that blue and violet zones have a high probability of containing frozen grounds (permafrost), while green and yellow zones might contain permafrost according to the characteristics of the area.

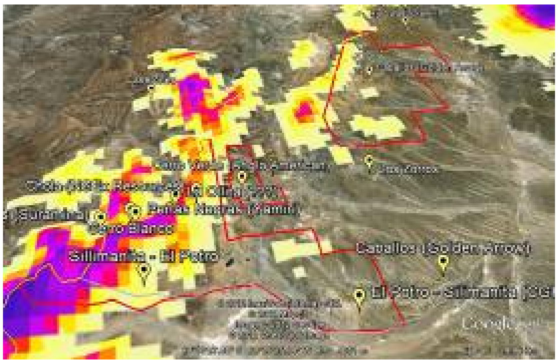


Agua Rica/Filo Colorado (Xstrata) - Catamarca
See: 27°22'03.60" S 66°12'21.89" W



Famatina (Osisko) – La Rioja
See: 29°00'33.83" S 67°46'33.36" W

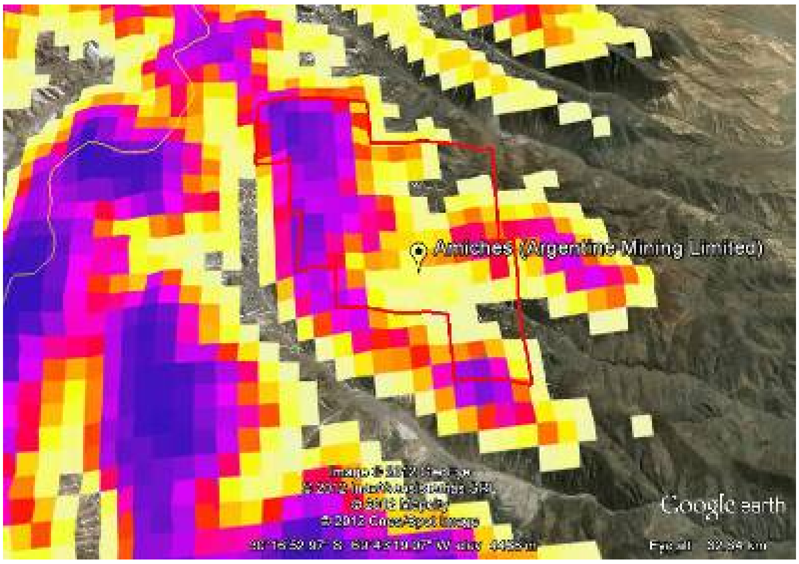
El Aguilar (Glencore) - Jujuy
See: 23°12'23.94" S 65°42'45.59" W



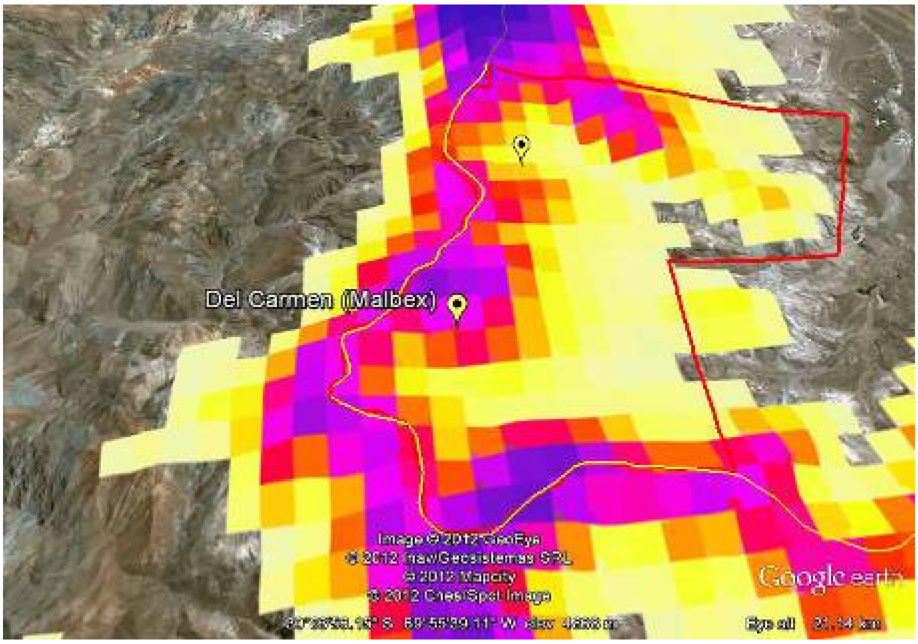
Numerous Projects along Andes in La Rioja Province
See: 28°19'43.51" S 69°29'12.43" W

San Juan is one of the areas where mining activity is most in conflict with periglacial environments. Below we can see the whole of San Juan's territory, with the permafrost map visible as purple and yellow areas. We can see the large coincidence of these areas with the yellow markers which are mining projects currently underway. We should note that we could only obtain a small portion of the nearly 200 projects that are underway in San Juan, since the information is not publicly accessible.

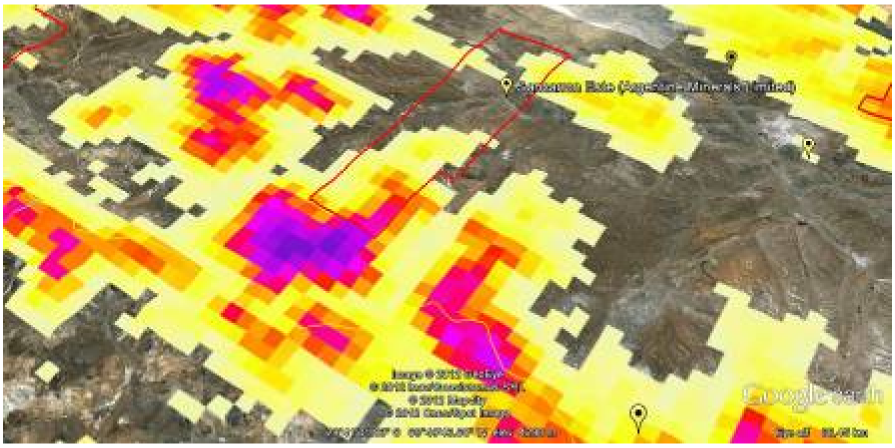
San Juan's provincial territory and Frozen Grounds (Permafrost) - Dozens of Mining Projects Coincide with Periglacial Environments



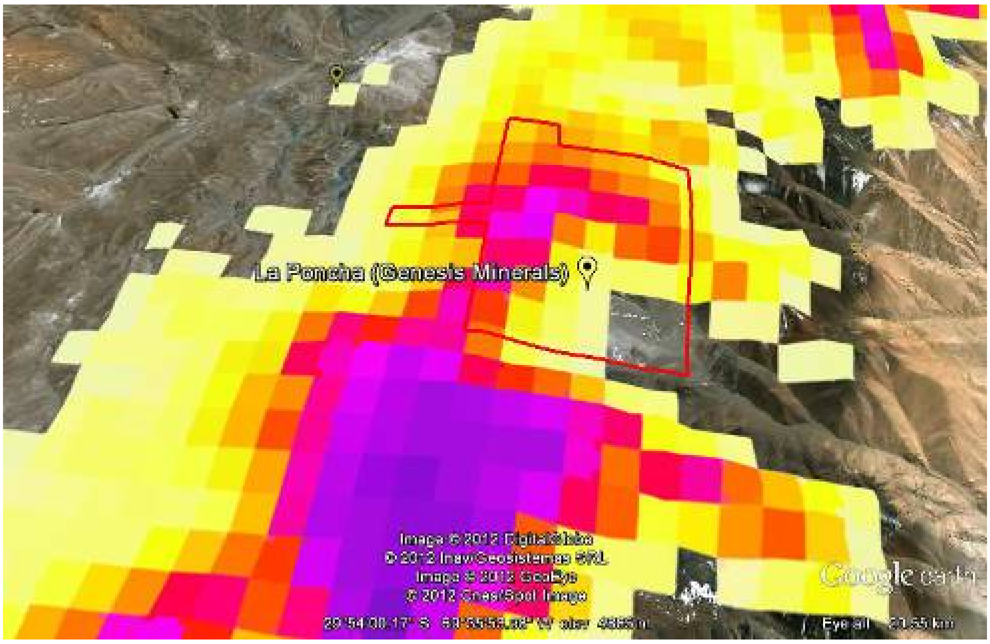
Amiches (Argentine Mining Limited) is entirely within periglacial environment
see: 30°15'07.77" S 69°42'55.05" W



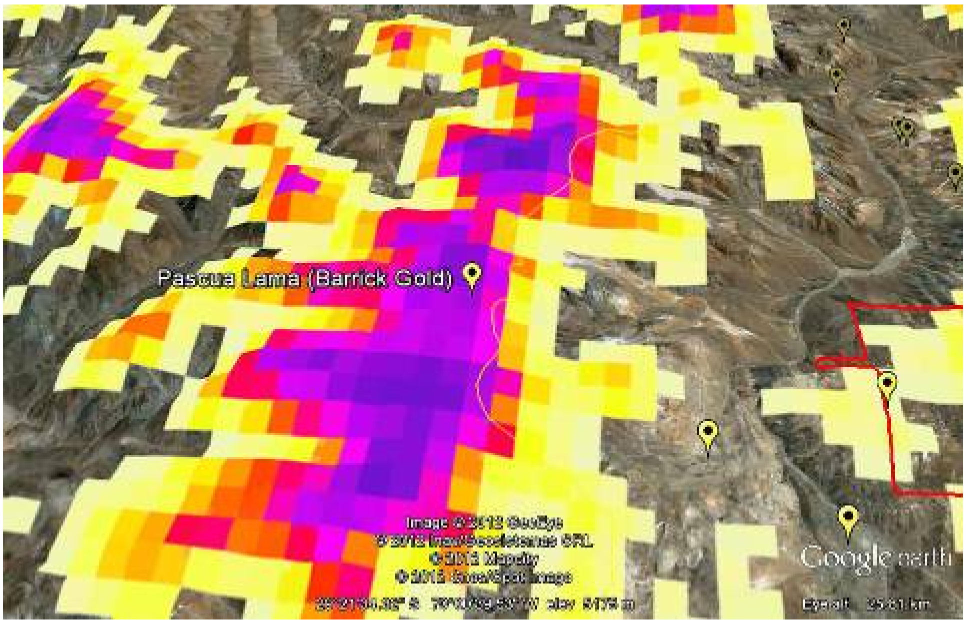
Del Carmen (Malbex): All of the project is on frozen grounds.
see: 30°02'19.63" S 69°52'35.98" W



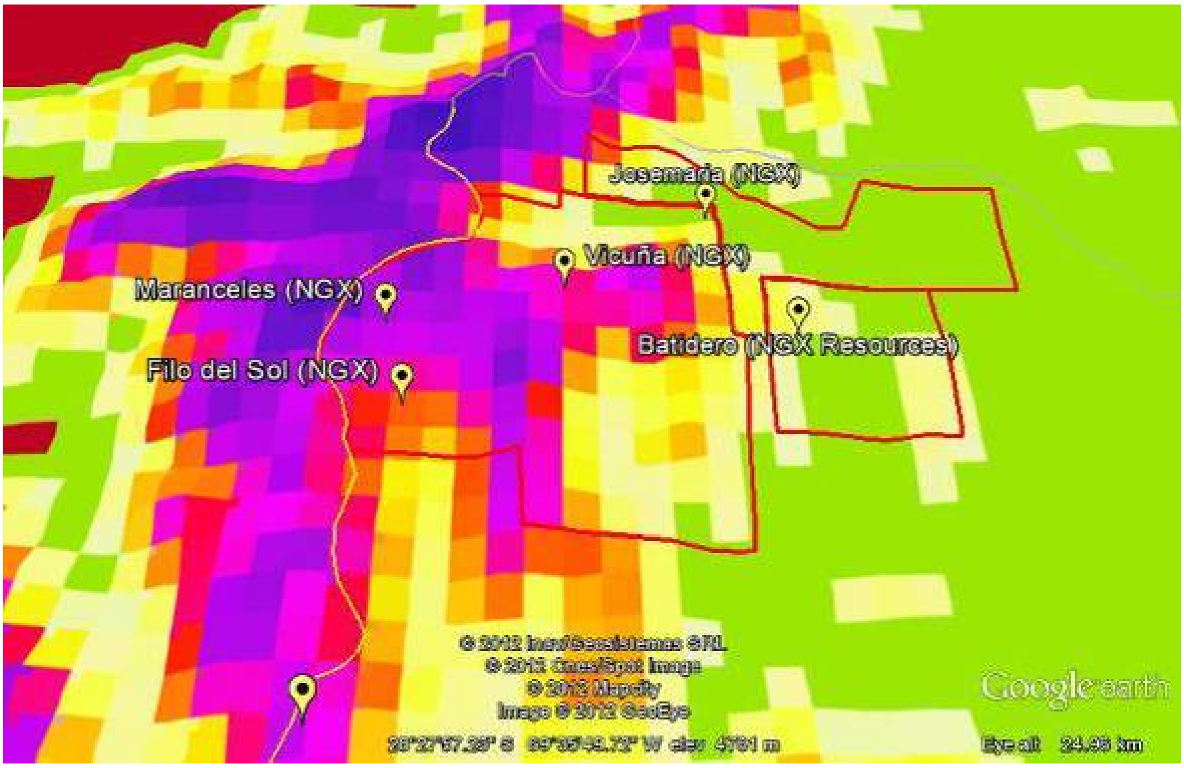
Sancarron Este (Argentine Wealth Minerals); nearly 50% in periglacial environment.
see: 29°37'47.11" S 69°45'06.33" W



La Poncha (Genesis Minerals): Nearly all of the project is in periglacial environment.
see: 29°52'39.04" S 69°34'30.90" W



Pascua Lama (Barrick Gold); 100% of the project is in periglacial environment.
see: 29°21'04.72" S 70°00'11.36" W



Frozen grounds and multiple projects: see: 28°27'57.23" S 69°35'49.72" W

In the annex of this report we list more than 50 mining projects that have been identified, mapped, and compared with the University of Zurich map, and in which this comparison reveals the coincidence between the project and periglacial zones. All of these projects have a high probability of being in frozen ground areas, and as such would be in the periglacial environment. For this reason, all of these projects should be carrying out detailed studies revealing glaciers and periglacial environments in the area of the project, as well as revealing the amount of water these resources provide. Past, present and future impacts to these resources should also be assessed.

Public authorities should be carrying out these “priority inventories” of glaciers and periglacial environment areas, specifically focused on these mining projects. Authorities should be obliging companies to produce these studies *before* they continue *any type of activity related to the extractives sector.*

Why should we distinguish periglacial environments?

If we carry out glacier inventories, and if we register rock glaciers, *without* registering the periglacial environment, isn’t that sufficient?

Definitively not! We must register periglacial environments, independently of glaciers and rock glaciers that may be container in periglacial environments, firstly because it’s a legal obligation for the State and for companies that are carrying out activities in periglacial environments.

We’ve published numerous studies with many examples of mining projects that are impacting rock glaciers. This impact is easily visible in satellite images as those available on *Google earth.* But the areas adjacent to rock glaciers, that also include frozen grounds, are also hence impacted, but simply, we cannot always verify through these satellite images, whether or not there are frozen grounds in these outlying areas. Nonetheless, we can infer that a mining exploratory road that penetrates a rock glacier or an uncovered glacier, also penetrated frozen grounds which do not manifest glaciers to get to the glacier in question. If these frozen grounds have ice, they are hydrological reserves and might be playing a key role as basin regulators.

What is certain is that the periglacial environment and its value as a water reserve and as a basin regulator, is far more extensive than the volume of ice in rock glaciers. This is deduced by simple logic since rock glaciers are only one part of the periglacial environment. The periglacial environment more generally, hence, is necessarily of greater surface area than the area covered by rock glaciers. With tools such as the global permafrost mapping by the University of Zurich, we have a very important approximation to the location of the periglacial environment area. It is not very complicated ten to see anthropogenic activity occurring in these areas. In this report, we've already seen numerous situations where important industrial projects are taking place or will take place in periglacial environments. We do not know how extensive the impact of this activity is. We only know that there is an impact and that it is significant.

Because rock glaciers are an element of the periglacial environment, impacts to rock glaciers are impacts to the periglacial environment. However, there are frozen grounds where there may not be a rock glacier, and yet there may be anthropogenic impacts to such frozen grounds. These would also be impacts to the periglacial environment.

The easiest way to begin an analysis of the impacts to periglacial environments would be to identify rock glaciers, and from there extend the analysis to those grounds that we see nearby the rock glaciers. In some cases, we will rapidly identify the periglacial environment by noting certain characteristics of the grounds. In others this will not be possible. It's important however, to identify impacts to frozen grounds because these are extensive ecosystems of the Central Andes, and they serve a critical role in the provision of water to rivers. Their invisibility make them especially vulnerable, and also for this reason, it is particularly important to pay special attention to periglacial environments, as they can suffer signficiant impacts if the necessary measures to protection them are not taken.

Consider the following example, in the sierras of the Aconquija in Catamarca Province. In the following image we see a mining road (introduced by Xstrata Copper) that has cut through numerous rock glaciers in order to get to Xstrata's *Filo Colorado* project. The reader can see this site on *Google earth* by going to: 27°19'50.53" S 66°13'59.76" W. The thin white line in the image is Xstrata's road, while the blue polygons are the rock glaciers.

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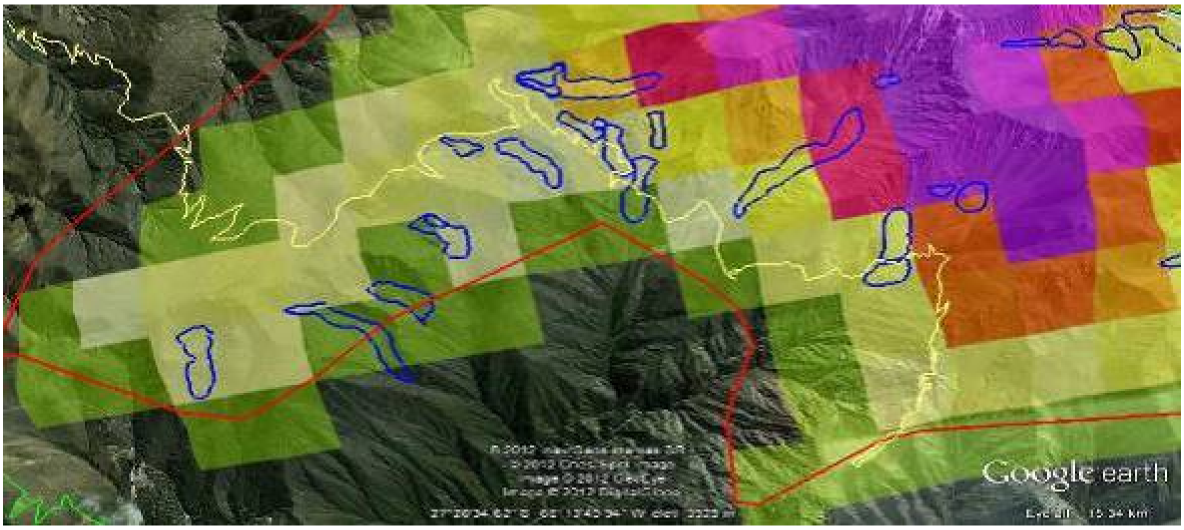
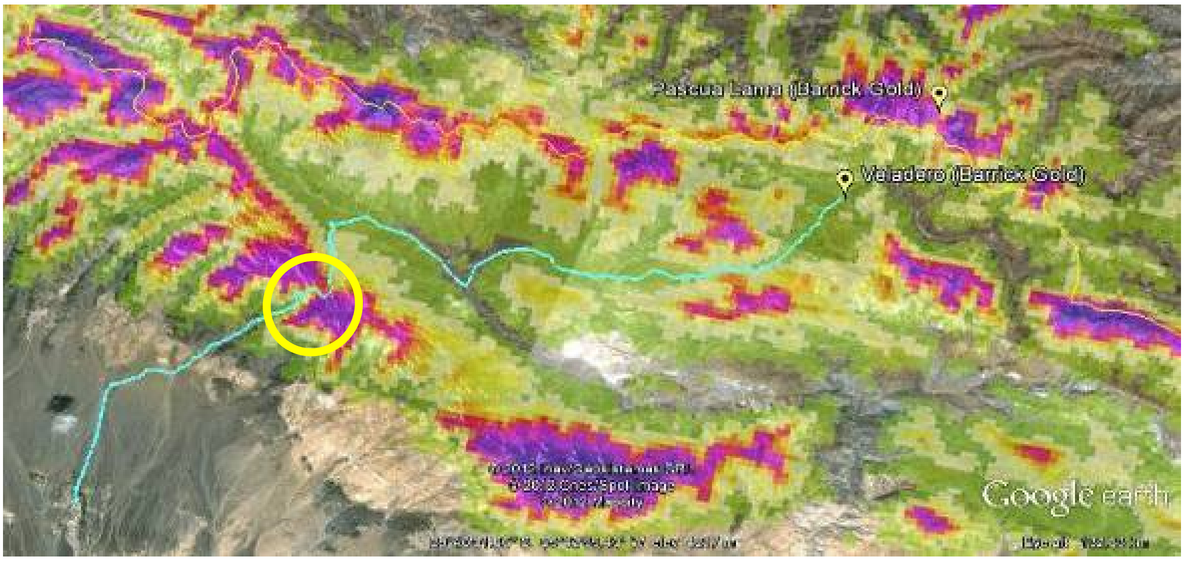
Road introduced by Xstrata Copper to reach Filo Colorado project impacts periglacial environments in Catamarca.

We can see in the next image (a bit further away) that all of the site, is potentially periglacial environment. We stress that the road (thin yellow line) was built by Xstrata Copper to get to its Filo Colorado project. We see that the road runs through extensive periglacial environment areas. With this tool, we can insist that any works that is carried out in this area, should avoid destroying periglacial environments and that is have the necessary studies to determine where those grounds are, identifying the presence of ice and the role that the periglacial environment has on the local hydrological systems. When we consulted Xstrata Copper as to whether they had carried out such studies of the periglacial environment of the region, the representative of the company indicated to us that we should not worry, since in this part of Argentina, there were no glaciers. Evidently Xstrata Copper had not taken into account, and in fact showed no concern over the presence of rock glaciers and of periglacial environments in its construction of this access road, which cuts into rock glaciers numerous times.



Permafrost mapping over Google earth image reveals that Xstrata's Road to Filo Colorado runs entirely through periglacial environment areas.

In the next image we see another mining exploration road (light blue line), in this case pertaining to Barrick Gold to access its' Veladero project. This road crosses through frozen grounds. The company should have produced a detailed study mapping the periglacial environment of areas were it planned to intervene with road work. The company should also have calculated the hydrological contribution of these frozen grounds. If it Barrick had done so, and if the State had insisted that the company to do so, Barrick would have identified the risks of sending its access road right through glaciers and periglacial environment, as it has done unnecessarily. Barrick has instead destroyed various glaciers due to this road, including the Almirante Brown Glacier, that was severed by Barrick's access road to Veladero and more than half of which has already disappeared as a consequence in the Conconta Pass. The road has also caused impacts to other glaciers such as the Norte Glacier, in the same area. The Norte glaciers will likely also disappear due to the impacts of the environmental contamination to the glaciosystem caused by this road. In the following image, we see the global permafrost mapping by the University of Zurich which shows the Conconta Pass and confirms that it is an area containing frozen grounds. (see yellow circle). If Barrick or the provincial government of San Juan had used a map such as this, they would have avoided this unnecessary impact.



We also stress the need to identify and study the periglacial environment closely (in addition to an in parallel to studies of glaciers or debris-covered glaciers) as they have particular characteristics that are different from these other glacier resources, and because impacts to periglacial environments can also be of very different character, albeit deriving from the same origins of impacts.

In sum, we can and should consider detailed studies of the impacts to frozen grounds *without rock glaciers* for several reasons:

1. because periglacial environments without glaciers, have different dynamics and properties from rock glaciers that may be found in them;
2. because the relative “invisibility” of periglacial environments make them more vulnerable in the face of careless anthropogenic activity;
3. because periglacial environments *without rock glaciers* can be important hydrological reserves, and/or water basin regulators, even more so in some cases than glaciers or rock glaciers;
4. because periglacial environments are much more extensive in terms of surface cover than the area occupied by rock glaciers;
5. because periglacial environments are also protected by law.

Mining and other Work Impacts on Periglacial Environments

Due to ignorance and/or disregard for glaciers, debris-covered glaciers, rock glaciers and/or frozen grounds (permafrost), mining operations taking place in the high Central Andes, have casued, *continue to cause,* enormous impacts on glaciers, debris-covered glaciers, rock glaciers and periglacial environments. Satellite images published in this report are but a few of the many images that are available and that attest to this impact.

Mining impacts to periglacial environments come from many aspects of mining operations, including:[4]

- Modifications to mountain sides whose particular shape and environmental conditions lead to the accumulation of snow and ice, the transport and accumulation of rock fragments, and the existence of the thermal condition of permafrost, which in turn allow for the formation of ice-rich permafrost and ultimately rock glaciers;

[4] compare Brenning, 2008; Kronenberg, 2009; Brenning & Azócar, 2010

- Disturbance of the delicate steady-state creep of the rock-ice mixture, which may lead to the collapse of the structure and ultimately the destruction of periglacial environments and/or rock glaciers;
- Explosions which may alter and collapse permafrost grounds/ice structures or destroy necessary glacier and periglacial environment containment valleys;
- Introduction of roads onto, adjacent to, or near periglacial environments (including rock glaciers), which can lead to modifications in meltwater discharge into the rock glacier, possibly reducing or inhibiting temporary and permanent water storage in the rock glacier, and modifying the surface heat flux which may possibly affect any underlying ice structure;
- Deposit of residues, waste rock, and other solids on permafrost and/or specifically on rock glacier surfaces which can lead to an acceleration of the permafrost's or rock glacier's flow and eventually to its collapse;
- Contamination of the periglacial environments surfaces, leading to color changes and material cover change, and subsequent temperature absorption changes, which could in turn lead to ice melt and eventual collapse;
- Contamination from the deposits made on the surface of frozen grounds, leading to acidic chemical and heavy metal drainage (acid rock drainage, ARD) into the ice and water of the periglacial environment, and possible permafrost degradation related to the heat created by these geochemical processes.

In the fololwing image we see a tractor plowing through a mountainside opening up a mining exploratory road. This is one of the most common images seen today in the high Central Andes of Argentina. This mountainside could be periglacial environment.

If the driver of this tractor has not been warned of the possible presence of ice in her trajectory, she will not detain her advance and may indeed plow right into an ice body or frozen grounds. This in fact commonly occurs in the region. The case we saw above of the destruction of periglacial environments of the El Altar project by Peregrine/Stillwater in San Juan Province, is but one extreme case where this has occurred.

In the past, mining companies paid no attention to ice conservation in their activities. On the contrary, ice represented an impediment to get at valuable minerals, and a complication for their operations. We see in the next image taken in a clandestine photograph by Barrick's Veladero workers, how Barrick's tractors cut the Almirante Brown glacier in half.

Uncovered glacier destroyed by Barrick Gold in construction of Veladero's Access Road in San Juan.

Mining equipment such as drills, regularly break when they encounter frozen grounds, glaciers, and periglacial environments, and this stops the exploratory or extractive process. Neither mining companies nor State officials considered that the destruction of these ice resources represented a significant impact on the hydrological value of the delicate high mountain ecosystem. This ignorance ended with the adoption of the National Glacier Law, although this *mal practice* has not necessarily ceased with the law.

The geo-cryologist, Corte, expert in permafrost and rock glaciers, says very clearly,

> "During activities in permafrost areas, there is a reduction of the active layer, either due to the effects of the wind, of transit and the erosion itself produced by water clearing, of fusion; but even worse is the influence of the "folding" caused by vehicular transit and the impacts of shovels and bulldozers that are used in the leveling of roads, parking areas, and access and service roads. For this reason, it is essential to consider the concept that permafrost must be protected at the highest degree in construction areas." (Corte 1993, p.295) – Unofficial translation.

For the introduction of any other type of work, be it the introduction of a road, a drilling platform for sample taking, etc. if it is known that the area is a periglacial environment area, the necessary measures to avoid impacts should be taken, to avoid impacts to the hydrological function of the resource or to the state of the reserve, or to the equilibrium of the periglacial environment.

The impacts of an anthropogenic work on a rock glacier is identifiable without the need of a site visit. Certainly, a site visit will be necessary to determine the extent of the impact, but the impact in many cases can be seen by satellite imagery. When the impact is in periglacial environments *with no rock glaciers*, this recognition is much more difficult without a site visit, and sometimes it may be impossible to detect.

It is possible to know ex-ante, through the review of satellite images, if a human work is affecting periglacial environments?

In some cases, yes. We can use the method by inference by examining satellite images to determine with great degree of probability if there are frozen grounds present, especially when we see the presence of rock glaciers in nearby areas.

It's relatively easy to identify a mining exploratory road via satellite images and also easy to follow the road to identify where it cuts through a rock glacier, since the rock glacier is a geoform that is very easily identified. The rock glacier flows on the surface of the terrain, and has characteristics that are very typical (lobular form, wrinkles in the form of arcs, crevasses, and a sharply cut tongue at 30-40 degrees), etc.. In the case of frozen grounds, *without rock glaciers present*, we cannot necessarily reveal the presence of frozen grounds so easily. We can suppose that in the vicinity of rock glaciers, especially at higher elevations than their lowest points, there will be periglacial environments present that may be affected. At least with this information, we can plan measures (command studies) to verify if there are or not periglacial environments present.

In the same way, if a road crosses a zone that figures in the global permafrost mapping tool by the University of Zurich as permafrost area, we should at least take note and later inspect this area and/or verify the situation on site, to determine if this frozen ground area is acting as a water reservoir or as a basin regulator. Many of these aspects concerning "where" will require specific studies, but initially can be determined at a distance, without a site visit, and it is for this reason that the priority inventories are so important. It is also an obligation of public authorities to ensure that mining projects that are taking place in periglacial environment areas are carrying out pertinent studies and that they do not advance works until these studies are completed. Many exploratory projects are advancing today in periglacial environments without these critical studies.

Let's review some images of rock glaciers and zones cited as frozen grounds, all affected by mining activity and other anthropogenic Works. This type of impact is very common above 4,000 meters in the province of San Juan, where at present there are more than 180 mining projects in exploratory phases. All of the mining projects in periglacial environments areas should carry out impact studies to determine if there are frozen grounds present and if these grounds function as water reserves, and/or water basin regulators.

There shouldn't be a single project in a periglacial environment zone, not even carrying out exploratory work, that has not carried out these studies and had them approved by the State.

If the State does not ensure this point, the public official would be failing to comply with her duties as a public official, in violation of the administrative and criminal law. Today there are several mining projects in the region that are advancing with exploratory work that have not completed studies. This is illegal.

a) Mina Aguilar (Glencore), Jujuy Province. Mining activity at Aguilar takes place on a rock glacier (marked by a blue oval in the image) that forms at the base of a mountain slope. We see that the extractive activity carried out by Glencore has destroyed a portion of this rock glacier, shown in the image to the left by a yellow oval. The image on the right, where we've super-imposed the permafrost map by the University of Zurich, shows that the glacier is located in a green zone, which means that the area is of uncertainty with respect to permafrost. This means that permafrost may occur under favorable conditions. The permafrost map alerts us to the possible presence of frozen grounds, but the rock glacier, clearly visible on *Google earth*, confirms the theory. We are in periglacial environment and Glencore is impacting this environment irreversibly because it is removing the ice. If Glencore had taken this "uncertainty" situation into account, and if they had carried out the necessary studies for the area, they would have quickly identified the permafrost presence before carrying out mass removal. This did not occur, and today, this mining activity is in violation of the National Glacier Law.

Jujuy provincial authorities should suspend activity at El Alguilar until the proper inventory and impact studies are completed, and until measures are taken to rectify past, present and any future damage to periglacial environments.

The reader can visit this site on *Google earth* at: 23 11 35.54 S, 65 43 34.43 W

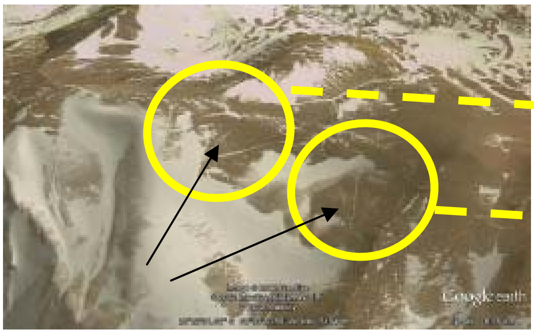
b) El Potro – Sillimanita (NGX Resources)

At the following site, two images of the same location on the border between San Juan and La Rioja provinces and with the international border with Chile (see: 28°20'34.66" S 69°33'20.59" W) – (the image to the right has the permafrost map super-imposed)—we see thin white lines which are mining exploration roads (identified with an arrow inside the yellow ovals). These roads were and are utilized to explore the concession of the El Potro Glacier. Individuals who frequent this area for tourism assure that the El Potro Glacier evidences numerous exploratory roads over its surface.

In the image to the right, we se the same the image from the same angle, with frozen grounds (permafrost) indicated as purple and violet areas. Clearly in this case, in the violet zones mapped by the University of Zurich permafrost model, there is a high probability that we will find the entire area to be permanently frozen ground, and as such, the introduction into this area of mining roads is almost certainly to have occurred on frozen grounds. If this situation is confirmed, and if these grounds contain ice, this is a violation of the National Glacier Law. These roads need to be rectified if they are affecting hydrological reserves, or if they are interfering with their function as water basin regulators. All activity of extractive projects in the area should be suspended and/or prohibited until proper studies can be carried out to avoid impacts to glaciers and to periglacial environments.

As in the previous case, if the authorities and the companies had taken into account frozen grounds *before* introducing these mining exploratory roads, they could have avoided this situation, which today is in violation of the National Glacier Law.

The government of La Rioja province should suspend all mining activity for the Sillimanita/El Potro project until it is sure that no part of this project affects glaciers and/or periglacial environments.



c) El Altar (Peregrine / Stillwater).

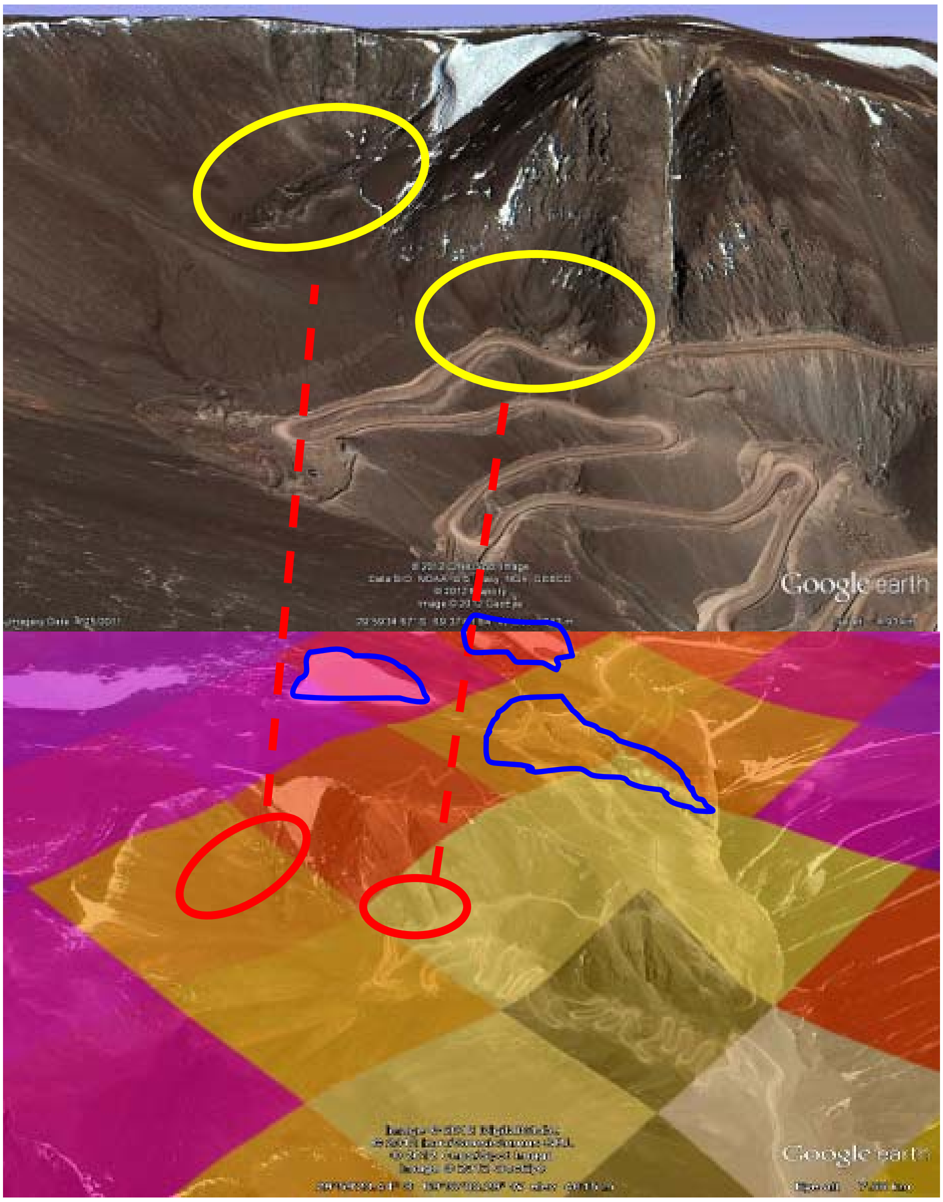
In the next two images (on the right the super-imposed permafrost mapping for frozen grounds done by the University of Zurich) we see again how mining exploratory roads utilized for drilling and sample taking dissect what appear to be active rock glaciers. In this case, we see at least four rock glaciers affected by this mining activity. And as in the previous case (Sillimanita/El Potro and Aguilar), we see that the global permafrost map alerts us of the possible existence of frozen grounds in the area. The green color in the map for the area indicates that there are possible areas of permafrost present, which in turn would imply the need to carry out studies *before* any activity advances in order to avoid impacts and not carry out activity that is in violation of the law. El Altar is currently violating the National Glacier Law. The presence of rock glaciers (already affected by mining roads) in the area of concession and exploration, confirms that we are in a periglacial environment area.

The government of San Juan should order the suspension of all exploratory activity at the El Altar project and insist that Stillwater produce a study on the impacts to rock glaciers that we see clearly in the image as well as to periglacial environment which is like present in the rest of the concession area. No par of El Altar should advance until it complies with the National Glacier Law.

The reader can see this site on *Google earth* at: 31 28 53.04 S, 70 28 49.31 W

d) Veladero/Pascua Lama (Barrick Gold).

In the following images in the province of San Juan, we see impacts by Barrick Gold on their access road to Veladero, on the Conconta Pass. At this site, Barrick removed frozen grounds to introduce its mining road for Veladero, which will also be used for Pascua Lama. At this site, Barrick has affected various rock glaciers and as such, also periglacial environments. We should mention that these impacts include impacts in addition to the already known impacts to the North Glacier and to the Almirante Brown Glacier. The images shown here have not been mentioned before in other documentation of glacier impacts by Barrick as they have only now been revealed due to improved image quality on *Google earth*. In the image we see *two active rock glaciers*, one of them affected by Barrick's access road. A consultation of the permafrost mapping by the University of Zurich reveals that these rock glaciers are in an area of probable permafrost. Today, with the new National Glacier Law in place, Barrick could never run its access road through this site. In the area near the top of the photo with the permafrost mapping, we also see that the North Glacier and the Almirante Brown Glacier are both in permafrost areas. This unnecessary impact could have been avoided had the company and the province taken into account the frozen grounds of the periglacial environment at the site.

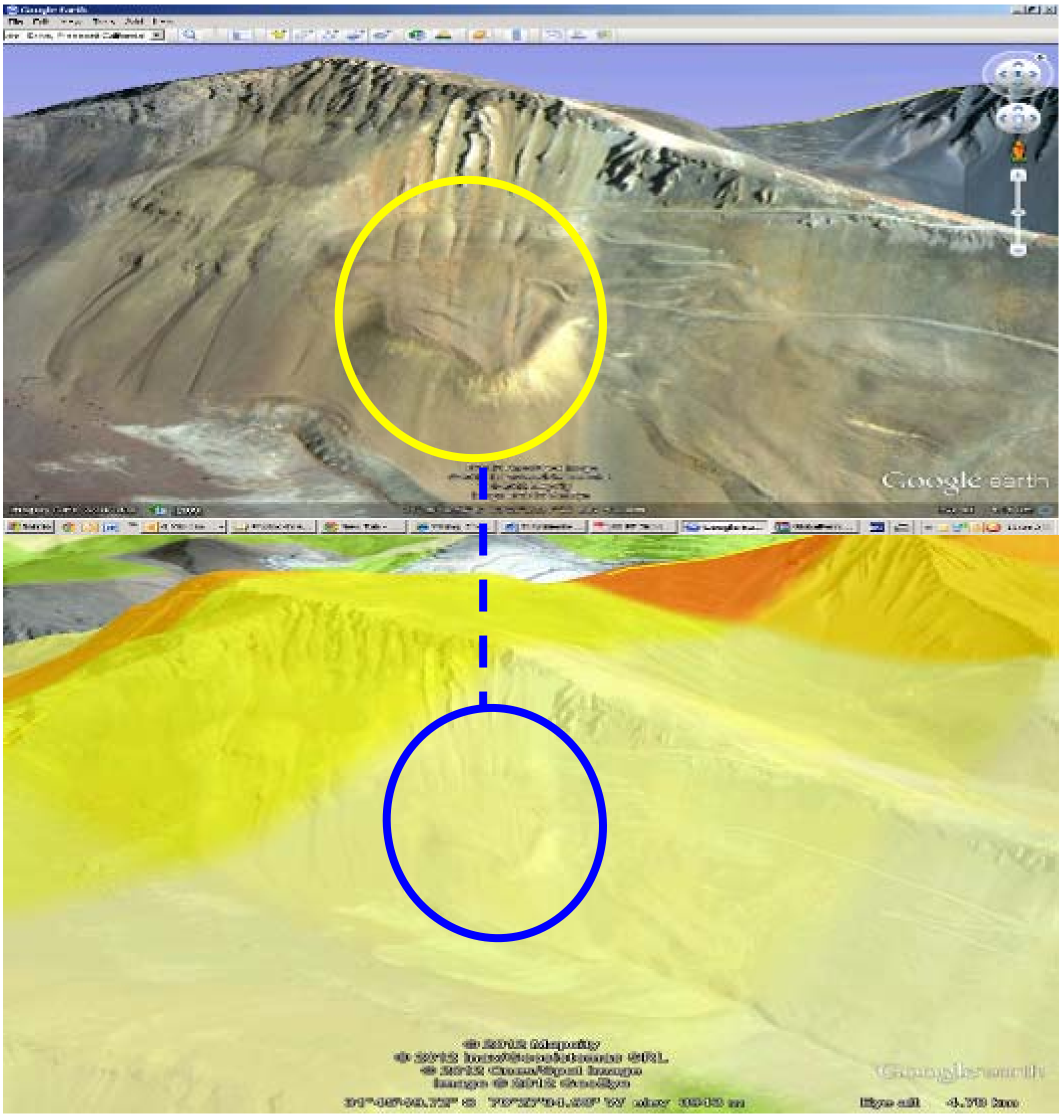


e) El Pachón (Xstrata Copper).

Again in the province of San Juan, we see how an exploratory road, this time at the El Pachón project by Xstrata Copper, has severed what is probably an active rock glacier, entering into the mass of the rock glacier, and probably cutting away a good portion of its active layer. This type of impact is common and could be fatal for the glacier is the necessary precautions are not taken to avoid disturbing the glacier's equilibrium.

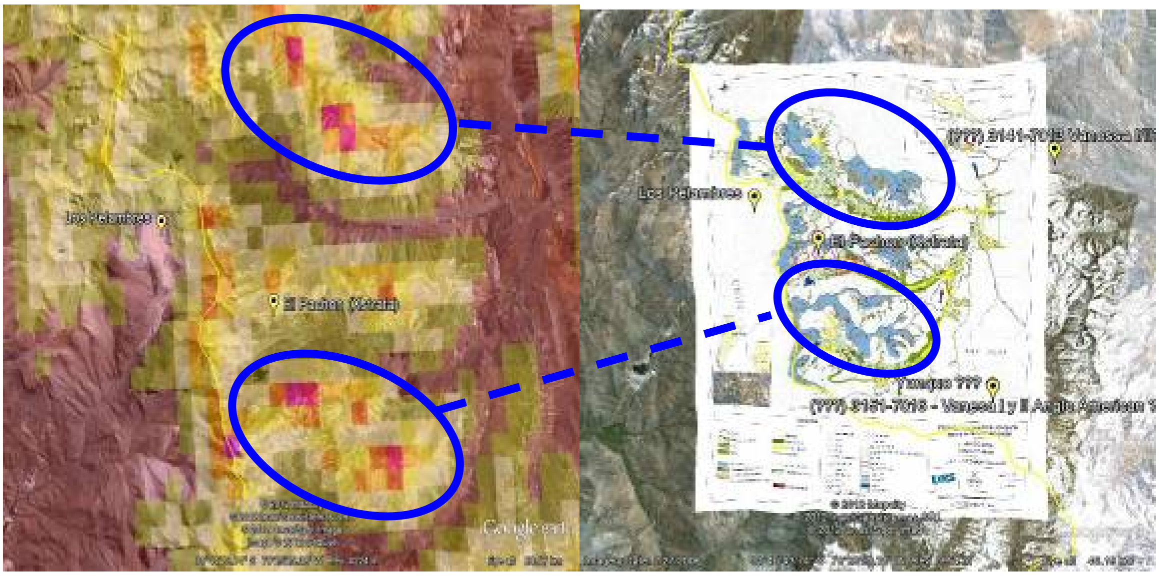
What can we deduce about this area from the global permafrost mapping by the University of Zurich. Again, this mapping provides us with critical information that is useful to avoid impacts. In the second image, we see that the area is categorizes as a permafrost zone, only in favorable environments (which is why it is in yellow). Considering that the mountainside is facing south, and that the rock glacier is between 3,900 and 4,000 meters above sea level (which is a favorable location for rock glaciers in the area), we can conclude that the presence of periglacial environment in the area is probable. If we take into account the National Glacier Law, this road should never have been built. If Xstata Copper is impacting the glaciers active layer, this impact needs to be reversed if the glacier is to be protected.

The reader can see this site on *Google earth* at: 31 45 48.54 S, 70 27 36.74 W.



We can use the El Pachón case for an interesting comparison of the permafrost model generated by the University of Zurich with the actual information produced by consultants hired by Xstrata Copper to carry out a permafrost and rock glacier mapping on site. URS, an experienced global consulting firm produced a permafrost map with rock glaciers identified for Xstrata Copper and the El Pachón project. If the model and the actual consulting work show correspondence, we can take this as an indicator of the usefulness and precision of the model for identifying periglacial environments.

URS mapped more than 200 rock glaciers in the El Pachón concession, and a bit more 20% permafrost. Lets then compare the images viewable on *Google earth* with the permafrost map by the University of Zurich (left), and the permafrost map produced by URS (right). Recall that the violet areas in the map on the left are the highly probable areas of permafrost, while the green areas are areas of uncertainty (there may or may not be permafrost present). In the map on the right, the blue zones are permafrost, verified by the URS consultants. The forecast by the University of Zurich, which is supposedly a theoretical model, is strikingly accurate, when we compare it to the actual analytical work of the area carried out by URS.



This simple exercise of comparing the theory with the practice serves to buttress the University of Zurich permafrost model as a very effective tool to forecast periglacial environments. The case of El Pachón provide remarkably consistent evidence between theory and practice when compared to the technical work carried out by URS.

Evidently, we cannot confide entirely in the permafrost mapping, as it cannot establish with precision where all of the permafrost areas are located. But we *can* utilize the permafrost mapping tool to determine which mining projects should produce studies on frozen grounds. For public officials of provinces such as San Juan, La Rioja, Salta, Jujuy, Mendoza and Catamarca, for example, the use of the permafrost map becomes a fundamental tool orienting official activity to control mining operations and in particular the implementation of the National Glacier Law.

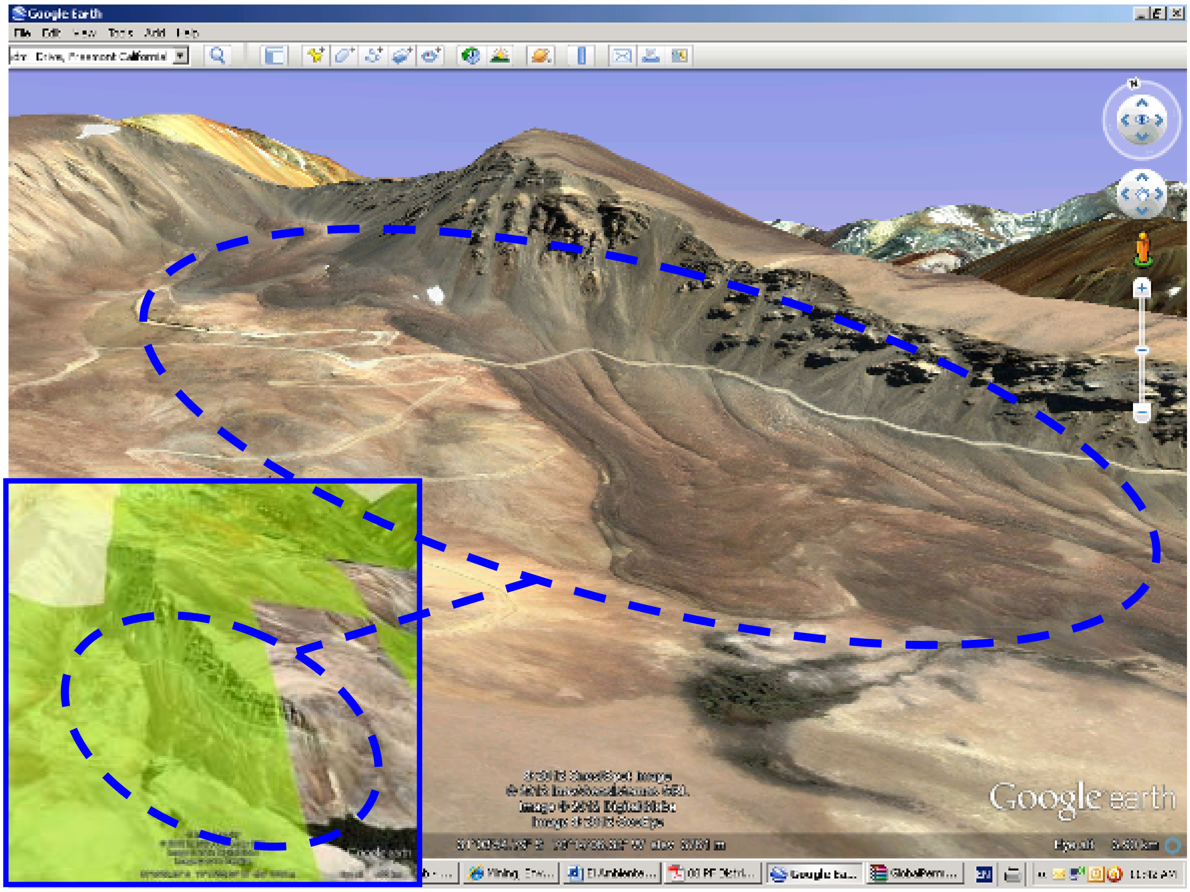
f) Los Azules (McEwen Mining).

In the next image we see how an exploratory road belonging to the Los Azules project (McEwen Mining of Canada), indiscriminately crosses an area rich in rock glaciers. We see in the image, the intimate relationship existing between the rock glaciers and the periglacial environment with the delicate vegas systems (mountain wetlands). The vegas in the area depend on the cyclical freezing and melting periglacial environments (the discontinuous permafrost zones) for their survival. A mining road that penetrates the active layer of rock glaciers, such as in this image, could terminally destroy the ecosystem.

In the lower left corner we super-impose the global permafrost map of the area. Again, we see that the permafrost map by the University of Zurich does not fail us, and indicates by the green color, that we are in a possible zone of permafrost if conditions are favorable (zone of uncertainty). In this case the south facing exposure of the mountain has allowed for the formation of rock glaciers and for the likely formation of more general periglacial environment. Field work and proper measures would have avoided this sort of impact caused by a poorly placed mining road. However, the Los Azules project commenced exploration activity before such studies were carried out, or worse, the company knew that they were destroying periglacial environments but continued with works anyhow. Today, McEwen Mining is about to initiate a new phase of exploration work at Los Azules, without having presented or completed any type of glacier impact study or studies covering periglacial environments. This is a flagrant violation of the National Glacier Law.

The government of the province of San Juan should insist that McEwen establish a clear glacier and periglacial environment protection policy (it has none), for Los Azules. The authorities should also insist that the company should carry out a detailed study of past, present and future impacts to rock glaciers and periglacial environments in the project area. Until this is complete, all activity, including exploratory activity, at Los Azules should be suspended.

The reader can see this area on *Google earth* at: 31 03 54.79 S, 70 14 06.32 W.



g) The Agua Negra Tunnel

It is not only mining activity that impacts periglacial environments in the area. Any large infrastructure project can impact frozen grounds and its function as a water reservoir and basin regulator if measures are not taken to avoid impacts. For this reason, the National Glacier Law stipulates that the proper studies are needed for all industrial activity that might affect glaciers and/or periglacial environments.

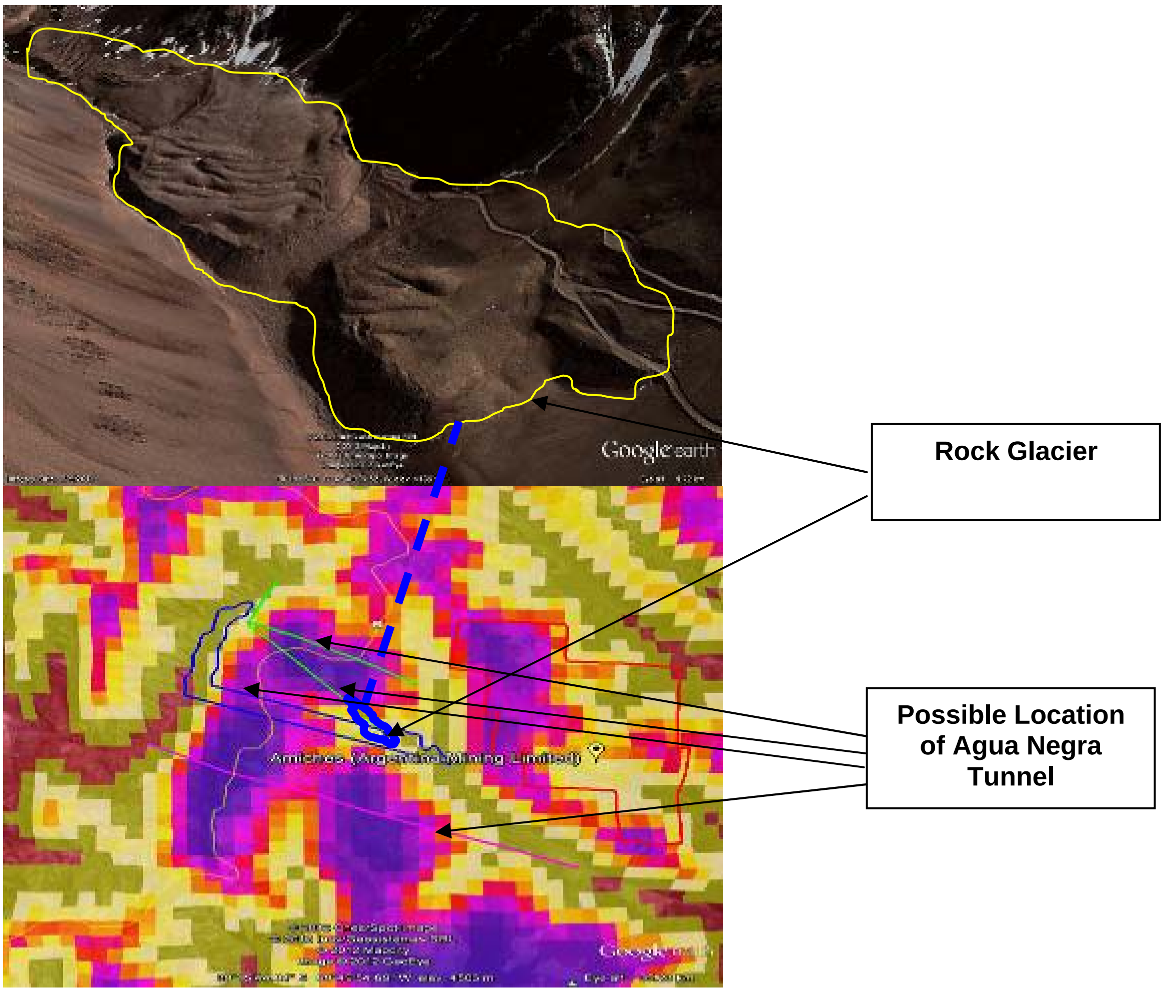
In the following image, which is incredibly vivid and clear on *Google earth* at:

30 14 58.43 S, 69 50 07.52 W,

we see a road and drilling platforms, situated on an active rock glacier. These is exploratory activity in the evaluation of a tunnel project which is to be carried out in the area, called Agua Negra.

In the second image, with the global permafrost map super-imposed, we see clearly how the options being considered today for the construction of the tunnel, all pass through frozen grounds. We see the small blue polygon corresponding to a rock glacier of the first image (the one with the roads on the surface), and we see multiple lines plotted (thin colored lines, blue, red, green) where the tunnel may be introduced. All of these options would perforate grounds that are permanently frozen (permafrost). To the right of the image, we also see the Amiches mining project concession (of Argentina Mining), which is approximately 50% on frozen grounds.

All of these situations are in violation of the National Glacier Law.



h) Road Works Affecting Periglacial Environments in Salta/Jujuy

Rock glacier experts Ahumada, Ibañez, Palacios and Paez, have published studies focused on road work impacts to periglacial environments.[5] This is the case of the border area between Salta and Jujuy provinces in the Sierra de Santa Victoria, visible at: 23°11'55.82" S 65°03'05.88" W

Road Works in border area of Jujuy and Salta cross rock glaciers and impact periglacial environments.

In the image we see how road work indiscriminately enters and exists rock glaciers and periglacial environments, impacting these resources and generating not only risks to the natural resource (to the water reserve, which is a violation of the National Glacier Law) but also generating instability in the public works, and recurrent problems in terms of land movements that occur in these frozen grounds.

In the next image we see how a road introduced by Xstrata Copper to get to the Filo Colorado project in Catamarca has also indiscriminately entered into rock glaciers . This site is visible at:
27 20 02.20 S, 66 13 27.75 W

5 see: http://wp.cedha.net/wp-content/uploads/2011/10/ahumada-palacios-paez-caminos-pune%C3%B1a-1.pdf

Risks of Mining in Periglacial Environment Areas

Why shouldn't we carry out extractive industry activity in periglacial environments?

First of all because it's illegal! Article 6 of the National Glacier Law is clear on this point. You cannot carry out activities that can affect the natural condition of the function of periglacial environments.

Periglacial environments that are saturated in ice function as water basin regulators. For this reason, they have a hydrological and strategic value that is key to the sustainability of ecosystems in arid areas. Mining activity contaminates the ground and waterways, either by the direct dumping of toxics such as cyanide or arsenic into waterways, or by acid drainage that can occur from sterile waste piles. Or simply by the mass movement of grounds in areas where minerals are being sought. This would affect the quality of the water contained in affected frozen grounds. The exploratory stages can also affect periglacial environments (in fact, perhaps even more so than the extractive phase), principally due to the removal of mass that can alter their function and lead to their deterioration.

The waterproofing that is carried out by mining companies to avoid acid drainage, is not always safe, and fissures in membranes can lead to acid drainage into the periglacial environment. If this occurs in frozen ground acting as a water basin regulator, the entire basin could be compromised.

But there are other reasons which are also important, as for example, the thermal properties and the geophysics of periglacial environments. Frozen grounds suffer permanent structural changes, expanding and contracting due to cyclical freezing and melting processes of the water they contain. We should recall that the volume occupied by water expands when the water is converted to ice. Simply putting a bottle of water in the freezer proves this point, when the ice forms, the bottle explodes from the pressure exerted from the expanding water. In frozen grounds, the results of freezing water are similar. Snow and water penetrate crevasses, etc. and when the water in these spaces freezes, the volume expands and the rocks break open, along with other materials in the ground. When the water melts again, it once again changes volume and new spaces are formed and the ground again is altered. For this reason, and due to the incline on the slope, and due to the lubrication by the water present, frozen grounds are in movement and could even slowly advance downhill on the surface of the slope.

We should also consider that any weight resting on the surface of the ice is also exerting pressure on the body, and if this pressure (weight) is significant (such as the millions of tons of waste rock places on sterile waste piles), this can generate excessive pressure and lead to a dangerous alteration of the geophysics of the ground.

We have a case in Argentina where exactly this has occurred. It's one of the most significant mining projects in Argentina, Barrick Gold's Veladero project in San Juan. At this project, according to glacier expert Juan Pablo Milana, Barrick Gold decided against recommendations of experts, placing a waste pile site on frozen grounds. Milana warned the government of San Juan that this was dangerous, as the frozen grounds are in continuous movement and could be altered by the weight, which could lead to an abrupt collapse of the waste pile.

Some time between end 2007 and early 2008, precisely this occurred. The collapse was colossal, a pile of waste rock the size of a small town crashed down several hundred meters of mountain side. The accident could have been tragic. The details of the collapse are documented in a report produced by Milana[6] and which was submitted to provincial authorities. The images of the collapse are surprisingly clear simply by consulting *Google earth* and using the time feature to compare passed images. Below we show the sequence of images that attest to this event.

The reader can see the before and after pictures, utilizing the time feature in *Google earth* at the following site.

29°22'45.00" S 69°57'40.58" W

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[6] see: http://wp.cedha.net/wp-content/uploads/2011/10/Landslide-at-Veladero-Juan-Pablo-Milana.pdf

Waste pile dumps, says Milana,

> "are planned to stay stable, since acid drainage of these dumps must be controlled. Accidental movements of waste piles not only imply risks to workers, but also an alteration to the original construction plan and a clear impact to the environment". (unofficial translation)

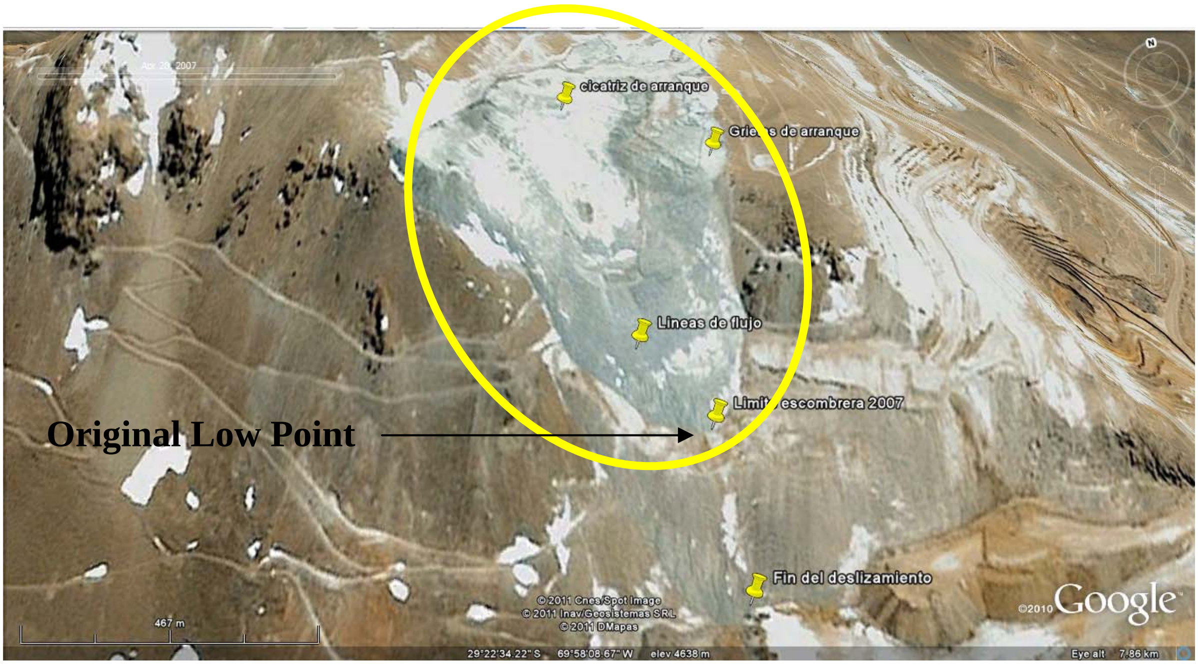
Milana suggests that the presence of frozen grounds at the Veladero site and where the collapse took place, could have been determinant in the fault of the construction by Barrick Gold. He severely criticizes Barrick's technical team for this design flaw:

> "The fact that a waste pile site collapses speaks very poorly of the engineering of the Veladero mine, since the engineers charged with determining the stability of the talus and taking into account that the slopes of these to not surpass the critical angles for the type of material and related hydrological saturation. What I think has occurred is that the necessary waterproofing of the waste piles to avoid acid drainage was not carried out and as a result, the material saturated with acid water and became fluid, slipping partially downslope, fortunately, not for a greater distance, otherwise it could have reached the lixiviation valley."

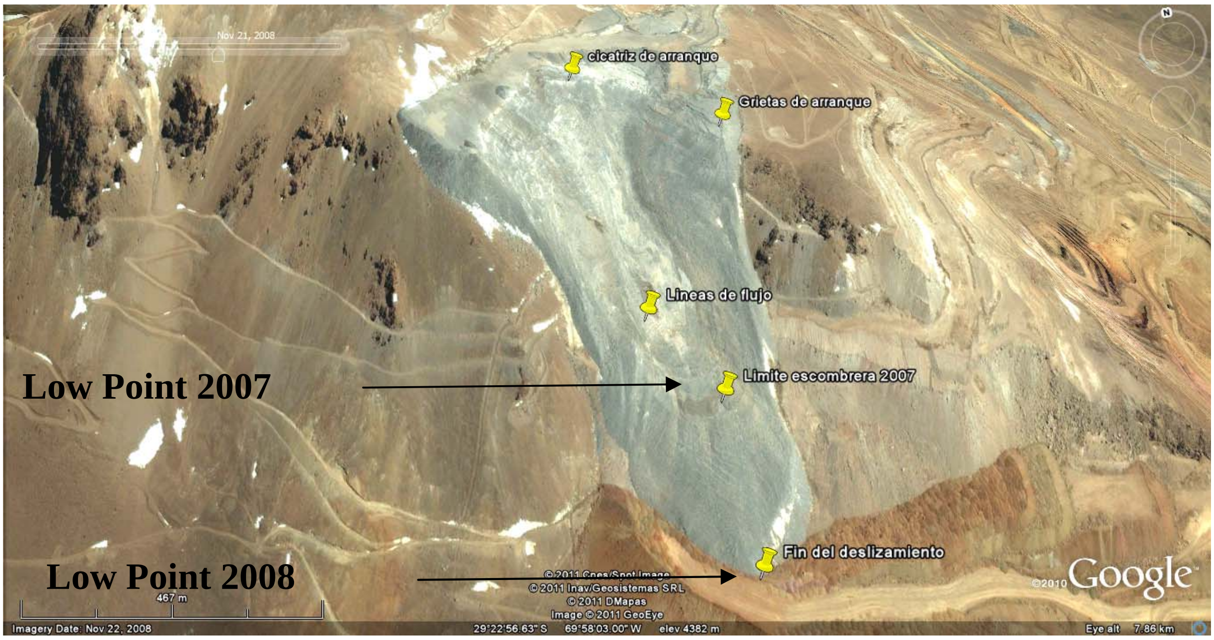
Milana's critique continues as a warning to the population of San Juan,

> "This is why, I hope that this case will serve to raise awareness for the population of San Juan, that there are very serious risks (including the very collapse of a lixiviation dam), and that the necessary security safeguards are not in place downstream of these projects to guarantee the safety of the community. It also teaches us that applied engineering in this project [Barrick's Veladero project] is deficient, and we should conclude hence that this or other worse accidents could occur in the future, NECESITATING independent controls."

In the next image we see the waste pile site in end-2007, before the collapse. The pile is a grey color, contrasting with the brown of the natural surroundings. We've indicated the site of the pile with a yellow oval. Note the marker placed by Milana at the lowest point of the pile. It will collapse from this point downward.



The following image shows the pile after the collapse, with a low point significantly lower than in the previous image. The difference represents several hundred meters of a colossal collapse.



We detain ourselves with the Barrick Gold projects (Pascua Lama and Veladero), not only because they are two of the most significant mining projects today in Argentina, but also because Barrick Gold systematically denies impacts to glaciers and to periglacial environments, despite numerous studies contracted by the company that say precisely what we are reporting here. Pascua Lama impacts and will impact periglacial environments that are in the project's area of influence. Numerous studies attest to the presence of ice and this generates serious doubts over the sustainability of these projects.

Consider the affirmations of the consulting group BGC Engineering, which were contracted by Barrick to study frozen grounds (permafrost) in 2009, centering on the Pascua Lama project area. The following table (we've translated select cells from Spanish original) summarizes the deplorable situation in terms of stability and safety of the future project activity areas, without considering the implications of contamination by acid drainage and direct contamination that can be expected by activity in these project areas taking place on frozen grounds. In this table, BCG summarizes in detail, that the principle activity areas for Pascua Lama, including the pit area and waste piles, are permafrost zones. If this area contains water, they are strategic reserves and water basin regulators protected by national law.

In the Executive Summary of the BGC report, we find alarming data in regards to the presence of periglacial environment, and in particular, to frozen grounds. In 14 excavations carried out, they found evidence of permafrost with an active layer ranging from 0.4 meters to 2.6 meters in thickness. In superficial ice, there is 23% humidity. Permanently frozen grounds (or permafrost) reaches up to 270 meters in depth (that's the equivalent of a 90-story building!). According to the technical experts, the same experts who recently offered a periglacial environment course at the National University of San Juan and in Chile, the frozen grounds of the project area appear above 4,000 meters and it is probable that frozen grounds exist as of 4,200 meters on slopes facing South and as of 4,800 meters on slopes facing North. Above 5,100 meters, it is probable that permafrost depth reaches more than 320 meters (that's frozen ground going almost as deep as the height of the Empire State Building!).

IANIGLA glacier expert Espizua, affirms in her work on Pascua Lama and Veladero (quoting Dario Trombotto and others) the presence of discontinuous permafrost, that is, permafrost that freezes and melts (thereby acting as a water basin regulator). Espizua states that in the area of the study, which is a

CMN / BEASA
Estudio de caracterización del Permafrost

Junio 25, 2009
Proyecto No. D442-005, D442-009

Tabla 8: Infraestructuras y permafrost.

		Comments	Probable Permafrost	Posible permafrost
Lama	Basin Area	Arroyo Turbio, 24.2 km^2	14.2 km^2	7.0 km^2
	Waste Pile Area	Possible the majority of area is permafrost	0.99 km^2	0.46 km^2
	Pit Area	All area is permafrost	0.91 km^2	0.01 km^2
	Plant Area	Only small parts are permafrost	Parcialmente	-
	Tailings Facility	No permafrost expected at this elevation	-	-
Pascua	Basin Area	Río del Estrecho, 35.9 km^2	18.1 km^2	14.2 km^2
	Esperanza Area	Entire area is permafrost	2.06 km^2	0.03 km^2
	Nevada Pile	Majority of area is permafrost	1.25 km^2	1.58 km^2
	Divisiones norte de los canales	La mayoría de los canales probablemente están localizado en permafrost	Si	Si

small portion of the influence area of Barrick's Pascua Lama project, that there are some 300 hectares (741 acres) of discontinuous permafrost. According to Espizua, this represents 17% of the discontinuous permafrost area of the Arroyo Turbio basin (Espizua, p.44). The pit areas of Pascua Lama, Penelope West, and Penelope East, the surface and sub surface conveyor belts, and the mining roads, says Espizua, would affect 170 hectares (420 acres) of discontinuous permafrost—that is, periglacial environment. The waste pile site, el Morro, she adds, covers a 170 hectare area (420 acres).

Protalus Rampart rock glacier at Veladero (Barrick)
Source: Espizua

In the next image, Publisher in the Espizua report, we see a rock glacier on a South-facing valley slope of the Arroyo Canito at 4,150 meters above sea level. The reader can see this rock glaciers at:

29°20'48.82" S 69°59'08.86" W

Espizua also makes reference to other types of bodies of ice in the periglacial environment, the so called Protalus Ramparts, that are according to Espizua, embryonic bodies of active rock glaciers.

These rock glaciers are not always easy to spot. They are also protected by national law.

According to Espizua, there are numerous glaciers located above 4,350 meters and below the -2˚ C isotherm.

We may also find inactive rock glaciers in periglacial environment zones. These are bodies of rock and ice that no longer display movement. It is often difficult to identify these glaciers from fossil glaciers, as they may have similar shapes.

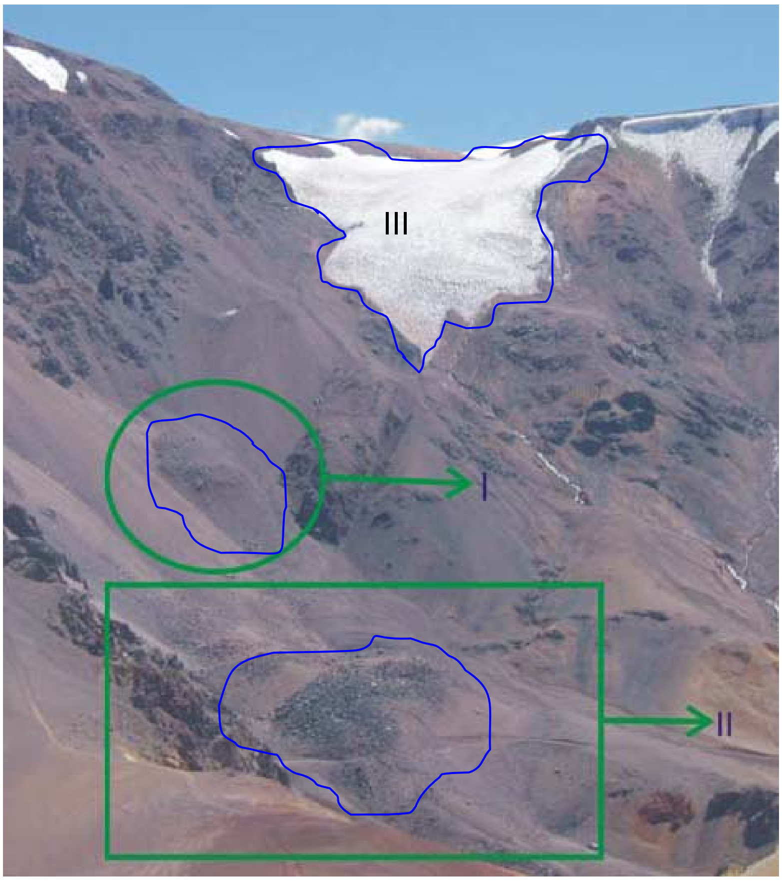
What is important to understand is that inactive rock glaciers can have a significant amount of ice in their interior. The following image taken by Espizua is of an inactive rock glacier in the Arroyo Turbio valley. Notice the difficulty of distinguishing this body of ice. According to Espizua, inactive rock glaciers appear as collapsed ice, smoothed out, and on occasion, may display vegetation in their frontal area.

Inactive Rock Glacier at Veladero. Source: Espizua

Below we reproduce an image in Espizua's report that helps us distinguish between the different types of glaciers and geoforms and ice that we might find in a periglacial environment. All of these are protected by the national glacier law. Many of these forms are very difficult to identify without proper training.

The following image contains:

I) A protalus rampart
II) An inactive rock glacier
III) An uncovered glacier (the Canito Glacier)



Types of Glaciers at the Veladero (Barrick Gold) site. Source: Espizua

The Glacier and Periglacial Environment Inventory

If we want to protect the periglacial environment, we first need to know where it is.

Officially, we do not yet know where Argentina's periglacial environment is located. There is no official mapping of the periglacial environment for the country.

Article 5 of the National Glacier Law states:

> **Art. 5º –** Implementation of the Inventory
> The inventory and monitoring of the state of the glaciers and the periglacial environment shall be carried out by the Argentine Institute of Nivology, Glaciology and Environmental Sciences (IANIGLA), in coordination with the national implementing authority of this law.

As indicated, the IANIGLA should identify, register and monitor:

- all glaciers of the country
- all of the periglacial environment of the country

The second point is key, and very clear in the national law. In practical terms, we understand by this that the inventory must register all of those elements protected by the law located in the periglacial environment, particularly those that are considered strategic because of their hydrological value, both as reserves or as basin regulators. In addition to inventorying uncovered and debris-covered glaciers, the inventory should include, in the periglacial environment:

1. active rock glaciers;
2. inactive rock glaciers

3. other cryoforms with ice (for example, protalus ramparts, although these might be considered rock glaciers)
4. permanently frozen grounds saturated in ice (or permafrost saturated in ice) … that does not necessarily evidence rock glaciers on the surface …

The timetable for implementation of the inventory presented in October 2010 by the IANIGLA,[7] the institution that is charged with carrying out the national inventory, stipulates that they will carry out an inventory of glaciers and cryoforms of the periglacial environment. In Section "5. Definitions Pertaining to the National Inventory" , the IANIGLA includes uncovered glaciers, debris-covered glaciers and rock glaciers. And then it indicates:

> "in the periglacial environment numerous geoforms exist with ice in their interior. However, as rock glaciers are saturated in ice, are the most important as regards hydrological reserves." (IANIGLA, Timetable p.21).

What is not clear from these indications is what will happen with the inventory of periglacial environments that don't display geoforms? That is, there may be frozen grounds with high ice content, but that do not manifest rock geoforms. Would these be inventoried? We contacted the IANIGLA with this question and the response that we received from the upper management of the institution was:

- that the IANIGLA will carry out inventory with regards to the concept of strategic hydrological resources (in compliance with Article 1 of the law).
- that grounds below 0 may or may not contain ice, we do not yet have studies indicating how much.
- they will study the contribution of water of frozen grounds during states 2 and 3 of the inventory, to determine if they are hydrological reserves.
- If the contribution is significant they will be included in future inventories.

We can conclude from this response that *if the periglacial environment is a strategic hydrological reserve it will be inventoried.*

In the meantime, and until this stage of the inventory is carried out in some future time, we can defer to the University of Zurich's tool, that for the moment, gives us a good basis to identify the presence of possible or probably frozen grounds. This is a minimum a first step, with which we can orient ourselves and with which we can also take decisions to demand that mining companies who would like to carry out activities in these areas, conduct the necessary studies on the periglacial environment.

Conclusions

The periglacial environment is a region in the high mountains that functions as a regulator of water basins. Additionally it is an enormous water reservoir critical to high mountain ecosystems. There is extensive periglacial environment in the Central Andes, and in particular in provinces such as San Juan, La Rioja, Catamarca, Tucuman (in the Aconquija mountains), in Salta and Jujuy.

The periglacial environment is important independently of uncovered glaciers, of debris-covered glaciers, and of rock glaciers (which are just one of the elements of the periglacial environment).

The periglacial environment is defined by properties that are particular to this resource that are different from that of glaciers and even of rock glaciers (which are just one of the elements within the periglacial environment). There are frozen grounds (permafrost) saturated with ice in the periglacial environment which serves as a critical water reservoir and which is protected by law.

There is mining where there are periglacial environments.

There impacts from mining and from other works (such as roads) where there are periglacial environments.

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[7] see: En: Inventario Nacional de Glaciares y Ambiente Periglacial: Fundamentos y Cronograma de Ejecución. P.21

This is a violation of the National Glacier Law. Where impacting activity exists prior to the glacier law, studies should be carried out to determine if the impacts should be repaired. Where activity is going on at present, it should cease until impacts can be assessed. And where activity is planned for a future date, they should not be allowed until we can carry out the necessary studies to assure that there will be no impact to these important ice, water and basin regulator reserves.

The National Glacier Law was approved unanimously by both houses of the Argentine Congress in 2008, and was vetoed just a few days later due to pressure from the mining sector because the Glacier Law represented serious commercial risks to the ability to carry out mining projects if the law were to stand. We can presume that the major worry of the mining companies in fact was not the protection of glaciers, but rather the protection of periglacial environments, which are much more extensive in cover than glacier cover or rock glacier cover.

Nonetheless, the law aimed to protect a crucial resource that is vital for all Argentines and for the ecosystems that depend on the glacier melt water each season, from mountains that store water in the form of ice in these periglacial environments. These hydrological resources are clearly far more important to the ecosystem than the precious metals that might lay underneath the surface of the mountain.

For this reason, congressional representatives understood that it was important to protect mountain ice, and the law returned from the veto in an improved version and passed again in 2010, after extensive debate, and despite strong opposition from the extractive sector. The president of Argentina promised she would not veto the Glacier Law if passed again and so, in October of 2010 Argentina became the first country in the world to pass a National Glacier Law number 26.639 which protects glaciers and periglacial environments, the "Minimum Standards Regime for the Preservation of Glaciers and Periglacial Environments".

Two mega mining companies, Barrick Gold and Xstrata Copper, and the provincial government of San Juan attacked the law in federal courts. They argued that glaciers are a provincial resource and as such they argued that the National Glacier Law violated constitutional rights. Other provincial laws appeared, all much less stringent, as for example, they fail to protect the periglacial environment or inactive rock glaciers. These provincial laws in part were attempting to preempt the National Glacier Law. Thankfully, at present, the federal Supreme Court has sided with strong glacier protection and has repealed efforts such as those by Barrick Gold and Xstrata Copper to undermine the National Glacier Law.

This report, which is a product of our *Democratizing Glaciers Series*, attempts to explain to non-glacier experts, the meaning and relevance of the Periglacial Environment, why it is important, where it is, what are the risks it faces, and what is the impacts caused to periglacial environments by mining operations and other large works (such as roads).

We are not against mining, but rather, we want to inform the public of a real risk and damage that is already evident in the high mountain areas to these sensitive hydrological resources. Glaciers and periglacial environments are being impacted by extractive industry activity. This impact can be avoided, it is not necessary that mining companies run roads through glaciers and through periglacial environment areas as they are currently doing. They can avoid this unnecessary impact, and the State should ensure that these companies are complying strictly with the National Glacier Law.

The responsible parties should assume their due diligence responsibility and act in conformity with the law.

- **The IANIGLA** should carry out the priority inventories in areas where mining and other works are taking place, where there are glaciers, rock glaciers and periglacial environment. The IANIGLA should also carry out an inventory of periglacial environments, which does not seem to be occurring.

- **Professionals dedicated to glaciology, geology, cryology, and geocryology** working on or dedicated to the issue in the region should work to protect glaciers, rock glaciers and periglacial environments, assuring and conditioning that their work (for example, when it is contracted by a mining company) should be publicly disclosed, and that it should be geared to the public interest.

- **Provincial Governments** should identify where mining operations and other works are taking place in areas where there are glaciers, debris-covered glaciers, rock glaciers or periglacial environments and insist that companies carry out the necessary studies to measure past, present and future impacts of the resource. They should provide the IANIGLA and the National Environment Secretariat with a complete list of mining operations underway (prospecting, exploration, and extraction). They should not issue work operating permits of any kind, including exploration or extraction permits, until pertinent glacier and periglacial environment impact studies are completed.

- **The National Government** should assure the enforcement of the National Glacier Law, and that the IANIGLA adequately carries out the glacier inventory, on time, and completely, and that this inventory include the periglacial environment that functions as a water reservoir and basin regulator.

- **Mining companies** and other companies carrying out infrastructure works in areas with glacier and rock glacier presence, or where there might be periglacial environments, should adopt operative policies and the necessary management systems to protect glacier resources. They should carry out glacier, rock glacier and periglacial environment impact studies, on the ice resources located in the area of their project and/or on access roads to the project. They should repair any past, present, or future damage, to these resources and they should provide all information they have on these resources to the general public, as these resources are of the public good.

- **The Justice System** should take all measures necessary to address the many complaints that have been made by interested stakeholders, to stop all activity that might be damaging glaciers, rock glaciers or periglacial environments, and assure that personas, companies, and public agencies responsible for these impacts, carry out the pertinent studies before they move forward with any new activity.

- **Organized Civil Society and Society in General** should stay alert and informed on situations where extractive activity or other activity might be affecting glaciers, rock glaciers, or periglacial environments, and should denounce such impacts when and where appropriate.

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ANNEX: Mining Projects underway in Periglacial Environments

All of these projects and/or works, are in permafrost (frozen grounds) areas, and in periglacial environments. We have no official information indicating that these projects have carried out the necessary studies to evaluate glacier, rock glacier or periglacial environment impacts. These activities should cease complete until impacts can be gauged.

The list is in geographical order from North to South. The reader can cut and paste the coordinates in *Google earth* to visit the site.

<u>Jujuy</u>		
El Aguilar (Glencore);	23°12'24.69" S	65°42'32.94" W
<u>Salta</u>		
Obras Viales:	23°17'12.82" S	65°01'10.82" W
	23°13'59.44" S	65°02'38.03" W
	23°16'39.39" S	65°01'12.41" W
<u>Catamarca</u>		
Filo Colorado (Xstrata Copper);	27°20'23.91" S	66°13'17.62" W
Agua Rica (Yamana Gold/Xstrata Copper);	27°21'47.82" S	66°16'33.19" W
<u>La Rioja</u>		
Caballos (Golden Arrow);	28°12'10.64" S	69°16'49.53" W
Vicuñitas;	28°17'56.34" S	69°26'34.20" W
Cerro Verde (Anglo American);	28°18'19.85" S	69°27'54.73" W
Chola (NGX Resources);	28°19'24.91" S	69°30'39.43" W
La Ollita;	28°19'48.71" S	69°31'39.57" W
Cerro Blanco;	28°20'05.97" S	69°33'33.79" W
Peñas Negras (Yamiri);	28°20'32.79" S	69°33'28.18" W
Sillimanita/El Potro (NGX Resources):	28°22'42.48" S	69°33'12.03" W
<u>San Juan</u>		
Portones (NGX Resources);	28°24'42.03" S	69°35'04.41" W
Jose Maria (NGX Resources);	28°24'58.85" S	69°32'49.70" W
Vicuña (NGX Resources);	28°26'30.35" S	69°36'10.94" W
Maranceles (NGX Resources);	28°27'02.46" S	69°38'53.13" W
Batidero (NGX Resources);	28°27'36.64" S	69°31'25.65" W
Filo del Sol (NGX Resources);	28°28'15.28" S	69°38'34.08" W
Proyecto No-Identificado;	28°32'12.31" S	69°39'22.35" W
Proyecto No-Identificado;	28°33'32.27" S	69°38'24.33" W
Cerro Amarillo/Cerro Dante;	28°36'05.34" S	69°36'29.62" W
	28°39'18.58" S	69°36'03.71" W
La Aparecida;	28°39'43.00" S	69°40'01.38" W
Las Flechas (NGX Resources);	28°42'48.30" S	69°39'38.92" W
Las Carachas (TNR);	28°45'38.11" S	69°30'04.11" W
Proyecto No-Identificado:	29°09'53.08" S	69°51'49.22" W
San Crispin (Entropy);	29°10'04.49" S	69°43'58.31" W
Proyecto No-Identificado;	29°12'04.01" S	69°52'19.17" W
Proyecto No-Identificado;	29°13'46.58" S	69°52'39.00" W
Mogotes (IMA Resources);	29°15'27.10" S	69°51'25.25" W
Proyecto No-Identificado;	29°18'41.28" S	69°50'18.96" W
Potrerillos (Golden Arrow);	29°21'28.60" S	69°51'17.61" W
Pascua Lama (Barrick Gold);	29°19'37.32" S	69°59'56.23" W
Veladero (Barrick Gold);	29°21'48.90" S	69°57'30.47" W
La Ortiga (Argentine Mining);	29°24'12.54" S	69°39'46.62" W
Sancarron Este (Argentine Minerals);	29°38'22.95" S	69°44'49.06" W
Jaguelito (Corporación América);	29°45'40.78" S	69°36'32.31" W
Proyecto No-Identificado;	29°49'17.50" S	69°39'47.37" W
La Poncha (Genesis Minerals);	29°52'20.04" S	69°34'33.75" W
Del Carmen (Malbex):	30°02'23.35" S	69°53'33.72" W
Amiches (Argentine Minerals);	30°15'19.20" S	69°42'39.58" W
Tunel Agua Negra;	30°14'39.28" S	69°50'42.87" W
Cerro Moro (Anglo American);	30°30'22.10" S	69°41'31.51" W

San Francisco (Argentine Minerals);	30°41'39.34" S	69°48'52.94" W
	30°31'42.92" S	69°50'30.24" W
	30°37'38.26" S	70°01'29.32" W
Proyecto No-Identificado;	30°47'13.08" S	69°53'31.04" W
Los Azules (McEwen Mining);	31°06'33.34" S	70°13'21.82" W
Rincones de Araya;	31°13'28.83" S	70°16'10.15" W
El Altar (Peregrine/Stillwater);	31°29'01.61" S	70°28'36.61" W
El Pachón (Xstrata Copper);	31°45'31.17" S	70°25'34.48" W
Proyecto No-Identificado;	31°51'52.72" S	70°16'33.93" W
Mercedario;	31°57'39.75" S	70°02'44.37" W
Amos Andres (Rio Tinto);	32°16'01.61" S	70°16'51.80" W

Mendoza

Las Leñas ski resort;	35°07'52.56" S	70°07'39.87" W
Cerro Amarillo (Concordia Resources Corp);	35°18'01.12" S	70°12'40.00" W

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