Andean Geology 41 (1): 248-258. January, 2014
doi: 10.5027/andgeoV41n1-a10

Andean Geology
formerly Revista Geológica de Chile
www.andeangeology.cl

GEOLOGICAL NOTE

New insights on the origin of the Mesón Alto deposit, Yeso Valley, central Chile: A composite deposit of glacial and landslide processes?

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ABSTRACT. The Mesón Alto chaotic deposit, located in the Main Cordillera at about 33°40'S, is an important landform with a volume of *ca.* 4.5 km^3 unconsolidated material deposited downstream of the Yeso Dam in the Yeso Valley, Río Maipo drainage basin. Historical work related this large deposit to a glacial origin whereas later on, it was assigned to a megalandslide that originated in the Cerro Mesón Alto Massif. First results of integrated fieldwork along with petrographic and geochemical laboratory work on granitoid blocks from five different portions of the deposit, compared with the major outcropping intrusive units in the neighbourhood (La Gloria Pluton, Cerro Mesón Alto Massif and Cerro Aparejo Intrusion) point to a landslide origin of the surface blocks. The results suggest that granitoid fragments of the deposit most likely belong to the Cerro Mesón Alto Massif, the proposed source of the rock avalanche. However, morphometric parameters and field observations support the idea of a rock avalanche deposited on top of glacial material. Therefore, the Mesón Alto deposit should be assigned to a composite origin. Confirmation of a post-glacial, large volume rock avalanche in a strategic area for existent infrastructure for Santiago water supply and ongoing energy projects is fundamental for a correct hazard and risk assessment of the region.

Keywords: Mesón Alto deposit, Landslide, Glacial material, Granitoids, Yeso Valley, Geological hazard.

RESUMEN. Nuevas observaciones sobre el origen del Depósito Mesón Alto, Valle del Yeso, Chile central: un depósito compuesto de procesos glaciares y de remoción en masa?. El depósito caótico de Mesón Alto, localizado en la Cordillera Principal a los aproximadamente 33°40'S, es un rasgo morfológico con un volumen de 4,5 km^3 de material no consolidado depositado aguas abajo del embalse El Yeso, en el valle del río Yeso, cuenca del río Maipo. Históricamente, este enorme depósito se relacionó con un origen glacial, mientras que más tarde fue asignado a un mega-deslizamiento proveniente del macizo Cerro Mesón Alto. Los primeros resultados de un trabajo integrado de campo, análisis petrológico y geoquímico de bloques de granitoides de diferentes sectores del depósito, comparados con datos de las mayores unidades intrusivas de la zona (el plutón La Gloria, el macizo Cerro Mesón Alto y el intrusivo Cerro Aparejo) apuntan a un depósito compuesto por bloques superficiales de procedencia de remoción en masa. Los resultados sugieren que los granitoides del depósito provienen del sector Cerro Mesón Alto. Sin embargo, observaciones de campo y parámetros morfométricos soportan la idea de una avalancha de rocas emplazada sobre material glacial. En consecuencia, se asignaría un origen compuesto al depósito del Mesón Alto. La confirmación de una remoción en masa postglacial de gran volumen en un área con infraestructura crítica para suministro de agua de Santiago y donde se emplazan proyectos energéticos en desarrollo es clave para realizar correctas evaluaciones del peligro y riesgo geológico en la región.

Palabras clave: Depósito Mesón Alto, Deslizamiento, Material glacial, Granitoides, Valle del río Yeso, Peligro geológico.

1. Introduction

The Mesón Alto sedimentary deposit is a *ca.* 4.5 km^3 deposit located in the Yeso Valley (33.6ºS, 70.1ºW, *ca.* 2,500 m a.s.l.), immediately downstream of the Yeso water reservoir (Fig. 1). It was originally assigned to glacial moraines formed by glaciers coming from the NNW (Marangunic and Thiele, 1971; Thiele, 1980), but later identified as a large rock slide and rock avalanche (Abele, 1984; Moreno *et al*., 1991) generated in the Cerro Mesón Alto andesitic and granodioritic massif (5,257 m a.s.l.), located immediately to the east of the deposit (Figs. 1, 2 and 3a). The deposit blocked three convergent valleys forming natural dams that remained over time, forming the Laguna Negra (water depth *ca*. 300 m), Encañado (water depth *ca*. 30 m) and Yeso lakes (water depth *ca*. 85 m) (Fig. 1). The latter was converted into an artificial water reservoir in the late fifties. The approximate thickness of the deposit is up to about 400 m and 250 m on average, according to gravimetric measurements (Marangunic and Thiele, 1971).

Recent geomorphological studies (Ormeño, 2007; Moreiras and Sepúlveda, 2012) have suggested that the deposit is actually composed by both

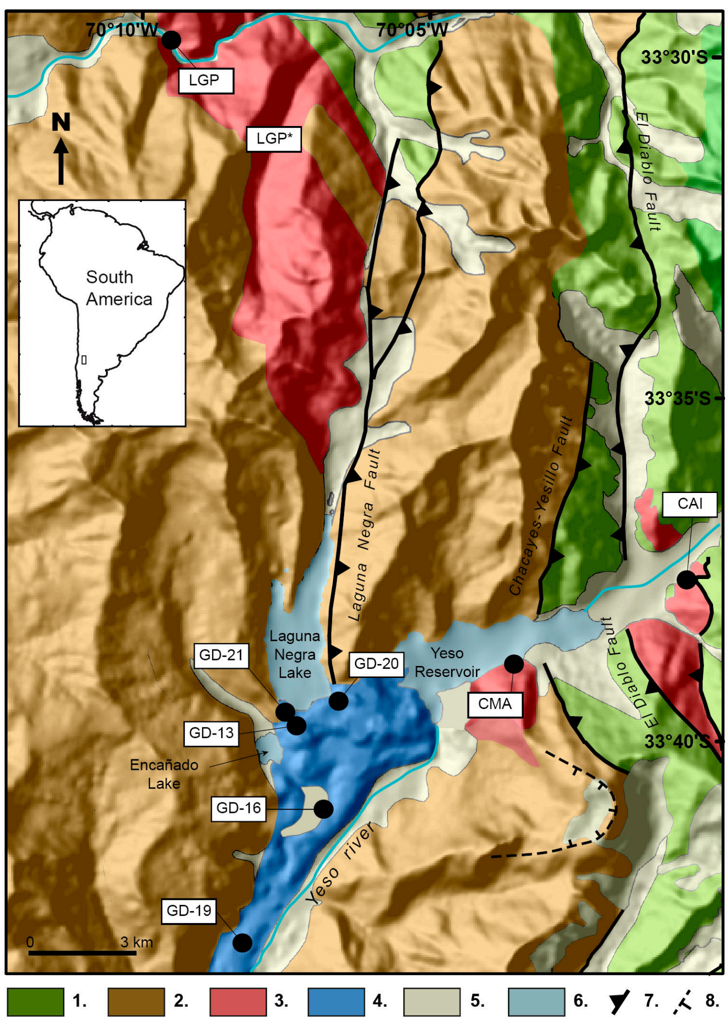

FIG. 1. Geologic map of the study area. Symbology: **1.** Mesozoic rocks; **2**. Oligo-Miocene rocks (Abanico and Farellones Formations); **3.** plutonic rocks; **4.** Mesón Alto deposit; **5.** alluvial deposits; **6.** water bodies; **7.** faults; **8.** landslide scarp; **CMA**=Cerro Mesón Alto Massif, **LGP**=La Gloria Pluton, **LGP***=La Gloria Pluton (Cornejo and Mahood, 1997), **CAI**=Cerro Aparejo Intrusion.

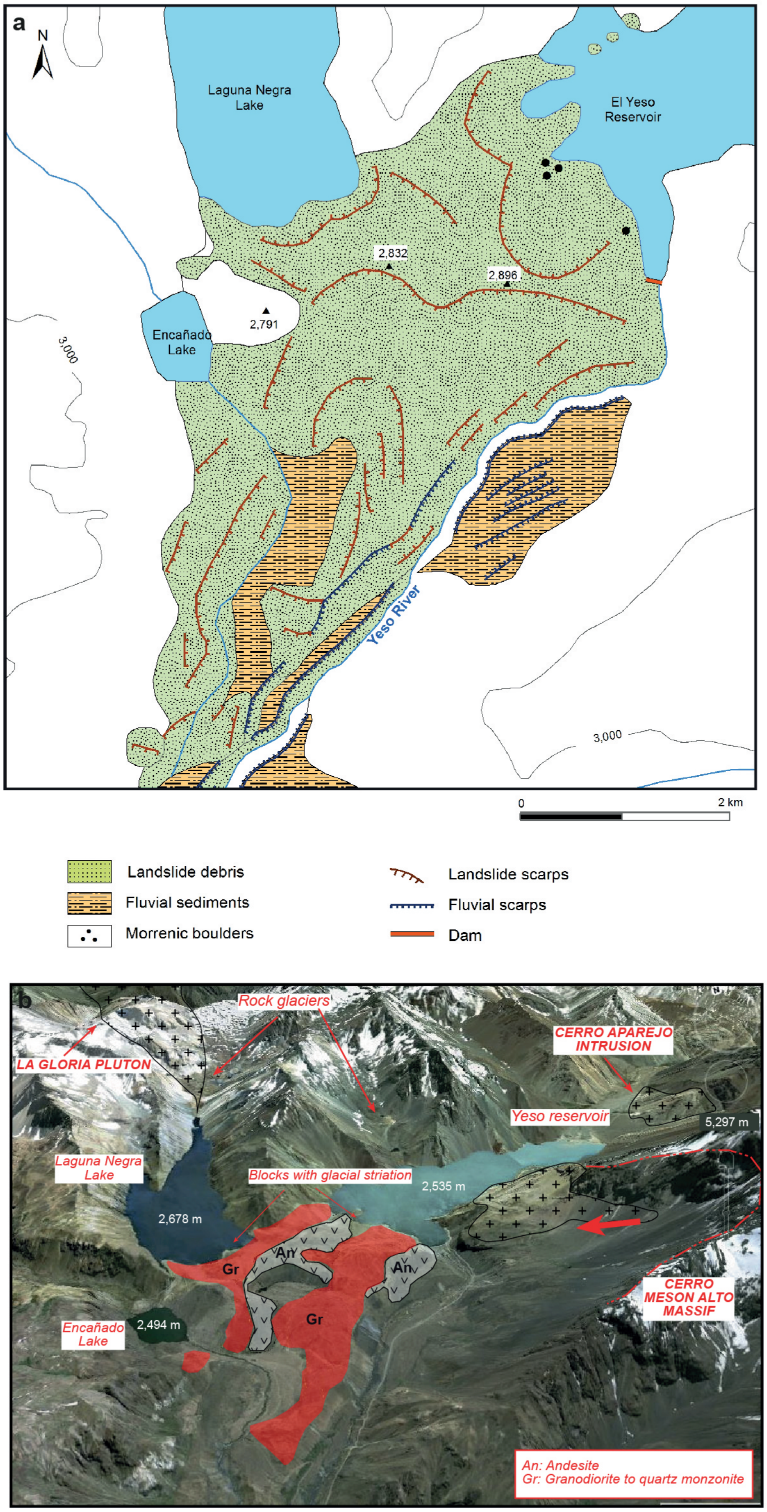

FIG. 2. **a.** Nature of the Cerro Mesón Alto deposit after Abele (1984); **b.** Mesón Alto deposit with alternating granite-to-quartzmonzonite (red) and andesitic rock detritus grey with 'v' frame. Plutonic bodies studied here are shown with a '+' frame. Modified after Moreiras and Sepúlveda (2012).

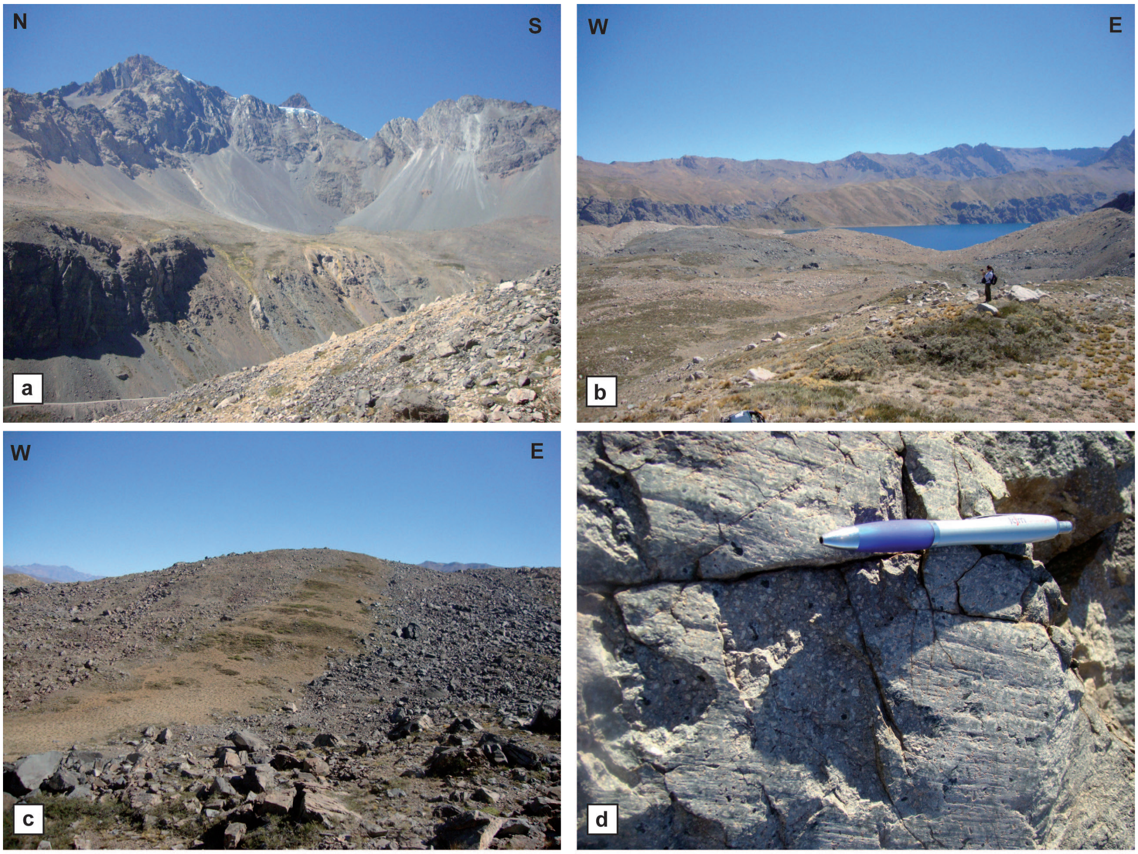

FIG. 3. **a.** Cerro Mesón Alto Massif and possible landslide source area; **b.** lithological bands within the deposit; **c.** vegetation pseudo-band in an andesitic band; **d.** striated block of likely glacial origin at the southern edge of Yeso Reservoir.

landslides and, to a lesser extent, glacial moraines. Antinao and Gosse (2009) identified the deposit as a megalandslide and dated it at 4.5-4.7 ka using the cosmogenic radionuclide ^{10}Be isotope, in a single point of the deposit, which indicates that at least part of it is definitively post-glacial. They suggested as a possible controlling factor for the slope instability the Laguna Negra Fault that crosses the area (Fig. 1).

To discriminate between a landslide and a glacial origin of such a large and complex deposit, a multidisciplinary approach is necessary. In this note, we provide new field observations as well as geochemical and petrographic analyses from granitoid blocks obtained from five different locations in the deposit, comparing them with both published data of two neighbouring plutons and new data obtained from another intrusive body. The intrusives are located in two different valleys upstream from the Cerro Mesón Alto Massif (Fig. 1). The goal of the petrographic and geochemical descriptions is to provide new information to elucidate the origin of the deposit. Our working hypothesis is that the blocks come from the Cerro Mesón Alto Massif, therefore the most likely origin for the deposit is a landslide process. Otherwise, the deposit should be of glacial origin. A positive answer about a landslide origin of this very large mass is key for understanding of landslide processes in the Santiago mountain region and correct geological hazard assessment of an area with evidence of historic seismic activity (1958 earthquake, Sepúlveda *et al*., 2008), landslide and debris flow due to sporadic strong rain events in austral summer time (most recent in January-February 2013) and presence of key infrastructure, such as the main water reservoirs for drinking water supply of Santiago city (Laguna Negra and Yeso Reservoir) and an ongoing large hydroelectric project, as well as increasing touristic activity. The results will orientate further research to fully understand the formation of this conspicuous landform in the Central Andes.

2. Geological framework

The study area is located in the Main Cordillera in central Chile (*ca.* 33°40'S), and dominated in the west by Oligo-Miocene volcanic and volcano-sedimentary lithologies, belonging to the Abanico and Farellones formations (*e.g.*, Charrier *et al.*, 2002). These were developed in an Oligocene to early Miocene extensional basin environment, and subsequently tectonically inverted between the early and late Miocene (Charrier *et al.*, 2002). On the eastern side, marine sedimentary and continental Mesozoic rocks crop out (*e.g.*, Giambiagi *et al.*, 2003; Fock, 2005). All units are affected by N-S oriented faults and folds. In addition, in the study area there is a strip of granite-to-quartzmonzonite plutons dated between 10 and 12 Ma (La Gloria Pluton, Cerro Mesón Alto Massif) intruding the Oligo-Miocene units (Fig. 1) (*e.g.*, Thiele, 1980; Cornejo y Mahood, 1997; Kurtz *et al.*, 1997; Fock, 2005; Deckart *et al.*, 2010). These plutons are located on the Laguna Negra and Chacayes-Yesillo Faults, which are west-vergent reverse faults (Fock, 2005; Fock *et al.*, 2006). The Laguna Negra Fault cuts the Abanico Formation and sills associated with the La Gloria Pluton. This structure also controls the morphology of the eastern edge of the Laguna Negra Lake. Besides, it has been proposed that this fault controlled the generation of landslides in the Yeso Valley (Fock, 2005; Fock *et al.*, 2006). Moreover, further east, a regional fault is observed, the El Diablo Fault (Fig. 1). This fault is presented by two branches with opposite vergence, from which one branch borders the Cerro Aparejo Intrusive (CAI) (Fig. 1) (Fock, 2005). This felsic intrusive is similar to the La Gloria Pluton and Cerro Mesón Alto Massif. However, the CAI has not been previously studied. Nevertheless, Fock (2005) assigns it to the same strip of Miocene intrusives to which both the La Gloria Pluton (LGP) and Cerro Mesón Alto Massif (CMA) correspond. All these intrusives could be the potential source and contribute to the recognized felsic clasts of the Mesón Alto deposit surface blocks (MADSB).

Concerning the origin of Mesón Alto deposit, if a glacial origin is postulated, blocks of diverse granitoids cropping out in connected valleys should be present in this deposit. Blocks of La Gloria Pluton and Cerro Aparejo Intrusion should also be identified in this deposit. Conversely, the existence of a unique precedence of granitoids would indicate a gravitational origin.

3. Description of the Mesón Alto deposit

Using a geomorphological approach, Abele (1984) discusses the possible glacial origin of this mass proposed by Marangunic and Thiele (1971), who described it as a moraine of a glacier valley coming from the Laguna Negra Valley. Abele (1984) describes a lack of mixing of the andesitic and granitic lithologies in the deposits along the shore of the Laguna Negra and lack of other lithologies present in that valley. Abele (1984) proposes that the deposit is composed by landslide debris, with very local moraine deposits (Fig. 2a). Several scarps within the deposit would reveal a series of local landslides originated in the mass (Fig. 2a). Fluvial sediments are recognized in a depression draining the Encañado lake, which were described as dam breaking deposits by Moreno *et al*. (1991).

Field observations of different parts of the deposit show that the Mesón Alto deposit has a chaotic texture showing blocks usually from 0.7 to 1 m in diameter, although some blocks could measure up to 4 m in diameter. No visible matrix could be identified on top of the deposit but along natural cuts the matrix content varies from 35 to 50%. Likewise areas with bigger blocks (>1m) and areas with a higher percentage of matrix exist.

The deposit shows heterogeneous lithologies, including granitoids, andesites, basalts and volcanic breccia blocks. Poor sorting and angularity of blocks/clasts are the main features of rock avalanches, however completely angular blocks could not be found in the deposit. They are mainly sub-angular and sub-rounded. This finding, together with the distribution of blocks in lithological bands may suggest a multiple provenance. This banding, easily recognizable at a distance in the field and on aerial images (Figs. 2b and 3b), shows, especially in the northern part of the deposit, an alternation of light-coloured bands with predominance of granitic blocks and dark-coloured bands with predominance of andesite and breccia blocks. This banding is quite a distinct feature, not only because it is not common in rock avalanche deposits, but because these bands, which have a NNE orientation, are roughly perpendicular to the expected displacement direction of a mobilized detrital mass from the Cerro Mesón Alto Massif, from east to west (Fig. 2b). Furthermore, within the andesitic bands there are pseudo-bands with a much smaller block content, where a superficial soil profile has developed associated with xerofic vegetation (Coirón: *stipa* sp.), which can be recognized by photo-interpretation (Abele, 1984) and in the field (Fig. 3c). These features are difficult to explain for a rock avalanche with a supposedly chaotic behavior and extremely rapid velocity.

Abele (1984) reported the presence of rounded material of possible glacial origin preserved at the base of the Yeso Dam, where blocks with striations were observed confirming their glacial source (Fig.3d). Ormeño (2007) also described a strip of moraine-like deposits at the Laguna Negra Lake shoreline. This was inspected in the field, where it is possible to observe a ridge with less blocks than in the rest of the deposit, with a local mixture of granitic and andesitic lithologies, and a few areas with a nearly complete absence of blocks. Some granitoid blocks are poorly polished in this sector; however, they are intensely weathered, disintegrated and showing exfoliation, which may suggest an older age.

4. Petrographic and geochemical data

In this study we present petrographic descriptions and geochemical characteristics of five recollected Mesón Alto deposit surface blocks (from now on MADSB), belonging to intrusive rock variety from different locations of the deposit, comparing them with potential source rocks of three intrusive units as introduced above, belonging to the immediate study area. These three intrusive units are the Cerro Mesón Alto Massif (CMA [samples FA-1, -3]; Deckart *et al*., 2010), Yeso Valley; La Gloria Pluton (LGP [FA-4, -5, -6]; Deckart *et al*., 2010), Colorado Valley; and Cerro Aparejo Intrusion (CAI, Yeso Valley, this study) upstream of the Cerro Mesón Alto Massif (Fig. 1, Table 1). Where possible, we include geochemical data and petrographic information of La Gloria Pluton samples (LGP*) from Cornejo and Mahood (1997) to increase the data set. The goal of this comparison is to determine which plutonic unit mainly provided the blocks of this unconsolidated deposit. In this way it is pretended to eliminate source rock candidates.

In this note we do not include the petrographic or geochemical characteristics of the andesitic lithologies of the deposit since the Abanico and Farellones formations are the only likely successions to be present in the deposit. Furthermore, in the study area and immediate around influencing zone, both formations crop out and trend north-south (Fig. 1), which makes it rather difficult to recognize from which direction and valley the material came from.

The five collected MADSB samples are: GD-19, which is a striated sample deposited some 7.5 km downriver of the Yeso water reservoir; samples GD-13, GD-20 and GD-21 were taken from the northern part of the deposit, close to the Laguna Negra Lake (Fig. 1), whereas sample GD-16 was collected in the central part of the deposit close to the Yeso River (Fig. 1, Table 1).

4.1. Petrography

Thin section observations show that MADSB samples GD-19 and in a less visible way GD-20 are characterized by a perthitic texture in feldspar minerals comparable to CMA samples but not recognizable in the other thin sections (Fig. 4a). MADSB samples GD-16 and GD-21 are characterized by fine-grained xenoliths composed of biotite, plagioclase altered to sericite, and amphiboles, likewise seen in samples from CMA (Fig. 4b). MADSB (GD-13) and LGP samples display a poikolitic texture which is not observed in other samples (Fig. 4c). CAI is generally a phaneritic rock which shows secondary minerals of epidote and sericite after feldspar and amphibole (Fig. 4d), different from the rest of the samples.

Looking in a more general way at the mineral composition obtained by thin section observation, the quartz content is variable with the lowest contents for MADSB samples GD-20 and -21, a fact that brings them closer to the CAI composition. The rest of the MADSB samples (GD-19, -13, -16) are nearer to the highest contents of the CMA intrusive, still, MADSB samples GD-13 and GD-16 are the highest in quartz regarding the entire sample set. LGP samples range between both extremes. Amphibole and biotite minerals are recognized in all samples except for the CAI sample, and some MADSB samples (GD-20, -21) lack amphibole. Since the CAI sample shows a strong replacement by secondary minerals such as epidote and sericite, feldspar and amphibole minerals are generally fully replaced. The

TABLE 1. COORDINATES OF STUDIED INTRUSIVES AND DEPOSIT SAMPLES OF THE RÍO YESO VALLEY, CENTRAL ANDES (33°30'-33°45'S).

Coordinates	Altitude (m a.s.l.)	Locality, Rock Type	References
401,432 E - 6,276.245 S	2,610	Cerro Mesón Alto Massif (CMA)	Deckart *et al.* (2010)
392,427 E - 6,293.008 S	1,485	La Gloria Pluton (LGP)	Deckart *et al.* (2010)
406,605 E - 6,279.018 S	2,640	Cerro Aparejo Intrusion (CAI)	this work
394,557 E - 6,268.650 S	2,110	GD-19, striated sample	this work
395,837 E - 6,274.405 S	2,745	GD-13, south of Laguna Negra Lake	this work
396,733 E - 6,275.021 S	2,770	GD-20, south of Laguna Negra Lake	this work
395,325 E - 6,274.761 S	2,720	GD-21, southwest of Laguna Negra Lake	this work
396,389 E - 6,271.723 S	2,455	GD-16, southeast of Encañado Lake	this work

mineral content for the feldspar group shows that plagioclase is dominant in MADSB samples GD-20 and GD-21, which are therefore similar to the CAI composition. The lowest plagioclase contents are observed for MADSB samples GD-19 and GD-16 which are similar to the CMA intrusive. GD-13 is the closest in plagioclase and amphibole content to LGP, which range between CMA and CAI. The feldspar content indicates the opposite behavior compared to the plagioclase content.

Samples from the CMA and two of three samples from the LGP and MADSB (GD-21), classify as quartzmonzodiorites, whereas the third sample from the LGP and MADSB (GD-16) show a monzogranitic composition (Fig. 4e). Similar compositional variations (from granodioritic to quartzmonzodioritic; LGP*) for the La Gloria Pluton have been already described by Cornejo and Mahood (1997). Furthermore, MADSB samples GD-13 and GD-19 plot in the granodioritic field, whereas MADSB (GD-20) classifies as quartzdiorite. The CAI intrusive sample represents a dioritic composition (Fig. 4e). In this presentation MADSB are overlapping with LGP rather than with CMA mineral compositions.

4.2. Geochemistry

Using major element analyses, the TAS diagram (Middlemost, 1985; Fig. 5a) classifies two LGP samples (Deckart *et al*., 2010), and MADSB (GD-19, GD-20) as quartzmonzonites. The third LGP and CMA samples (Deckart *et al*., 2010) as well as MADSB samples GD-13, GD-16 and GD-21 are represented in the granitic field. LGP* samples from Cornejo and Mahood (1997) occupy the same fields as LGP samples taken from Deckart *et al*. (2010), *i.e.,* quartzmonzonitic to granitic. The CAI sample plots at the limit of the quartzmonzonite and quartz syenite fields, separated from the rest.

Harker diagrams (Fig. 5b-e) with major and some transitional elements show that generally all five MADSB samples plot within or close to the CMA field, as does one LGP sample (Fig. 5b, c, e; FA-5), but are very different from the CAI sample. CAI is the less enriched sample in SiO_2 (Fig. 5b-e) and K_2O, but the most enriched in TiO_2, Na_2O, CaO, P_2O_3 and Al_2O_3 (Fig. 5b) of the entire data set. Regarding the MgO vs. SiO_2 diagram a slight separation between LGP/LGP* (more enriched in MgO) and CMA and the MADSB samples (less enriched in MgO) is apparent (Fig. 5c).

Commonly, major element compositions slightly separate CMA and all MADSB samples from the LGP/LGP* and in a more pronounced way from the CAI.

Transitional element concentrations such as Cr and Ni are lower and Sc is higher in CAI compared to the rest of the analyzed samples (Figs. 4e, f). Ni and Sc *versus* SiO_2 slightly separate LGP samples from the rest of the data set. Ba is higher than 500 ppm in all samples excluding the CAI sample where Ba is much lower at about 300 ppm.

It has to be noted that the most altered sample is that representing the CAI intrusive, visible through its secondary mineral composition of epidote and sericite. The rest of the samples can be classified as slightly meteorized with low secondary mineral presence. This aspect might influence in some way the major and trace element geochemistry especially regarding the K, Na, Ca and Al concentrations. Nevertheless, the mineral composition itself indicates

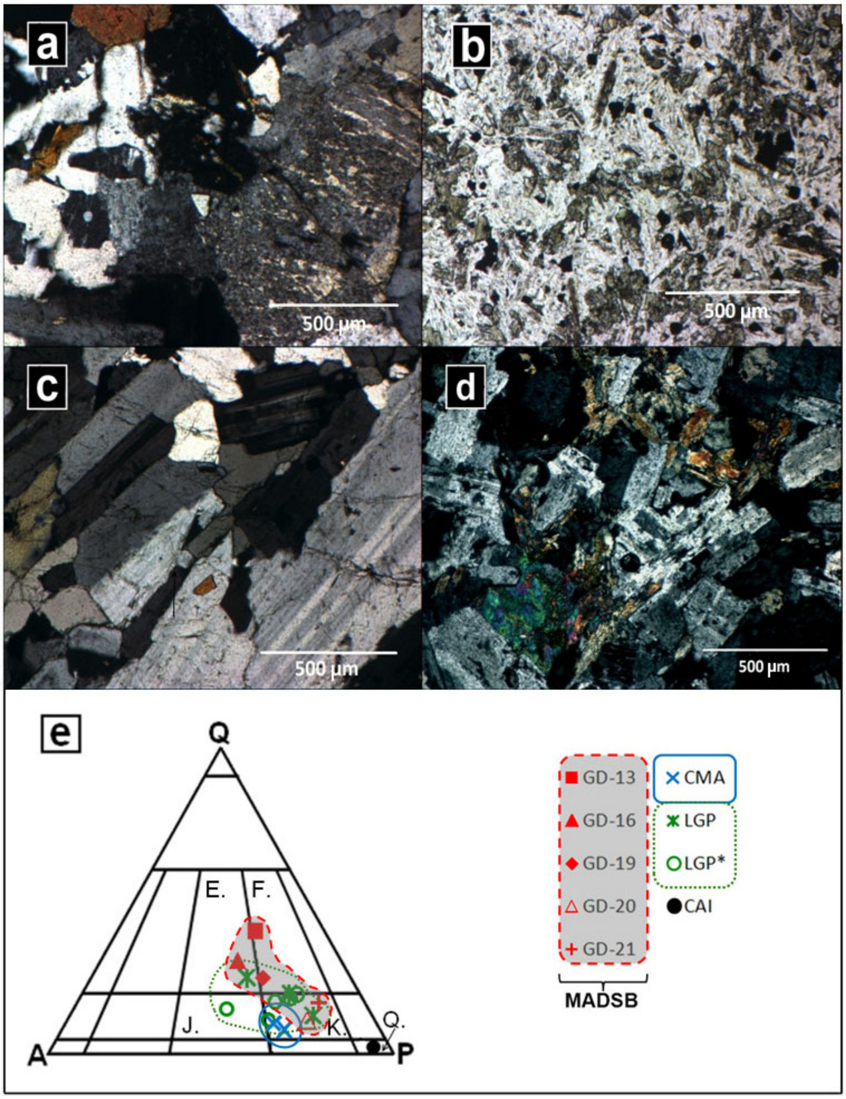

FIG. 4. **a.** CMA (FA-3) in cross-polarized light with characteristic perthitic textures in potassic feldspar; **b.** CMA (FA-1) plane-polarized light of a mafic enclave; **c.** LGP (FA-4) in cross-polarized lights with characteristic poikolitic textures; **d.** CAI in cross-polarized light with phaneritic texture of plagioclase and feldspar replacement by epidote; **e.** QAP diagram in modal composition for plutonic rocks (Streckeisen, 1976) with fields **E:** monzogranite, **F:** granodiorite, **J:** quartzmonzonite, **K:** quartzmonzodiorite and **Q:** diorite.

geochemical variations in at least these elements since the plagioclase (Ca, Na, Al) and potassic feldspar (K, Na, Al) contents are visibly variable and therefore influence the geochemical composition of each rock.

Regarding the rare earth element (REE) concentrations, CAI is the most enriched sample except in its La concentrations. This light-REE seems to be a little lower compared to the rest. MADSB samples GD-13, GD-16, and less pronounced, GD-19, are very similar, but slightly different from the rest. MADSB samples (GD-13, -16, -19) show a trough-form towards heavy-REE, which is not observed in the rest of the samples. MADSB sample GD-19 is the less and GD-16 the most enriched in light-REE.

It is noteworthy that while petrographic analyses are not conclusive, geochemical observations indicate that all five MADSB samples are largely similar to the CMA and one LGP (FA-5) but slightly different

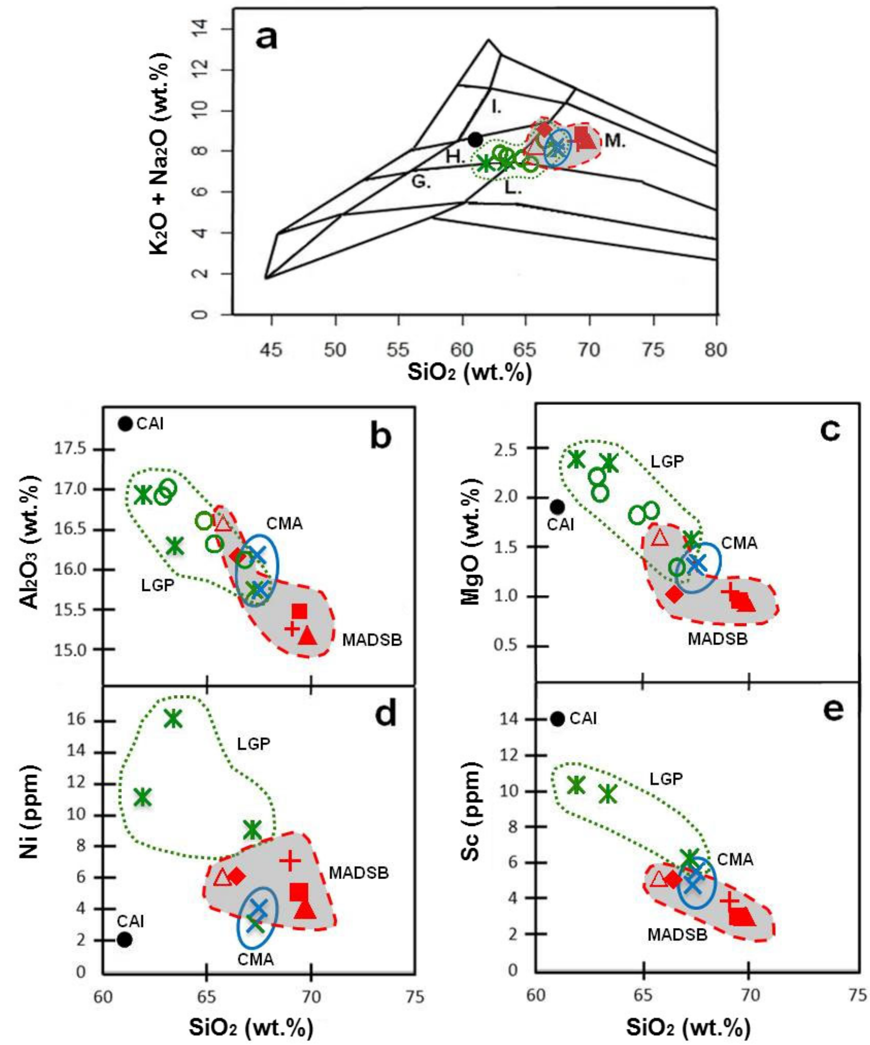

FIG. 5. **a.** TAS diagram (Middlemost, 1994) with fields **H:** quartzmonzonite and **M:** granite; **b.** SiO_2 *versus* Al_2O_3; **c.** SiO_2 *versus* MgO; **d.** SiO_2 *versus* Ni; **e.** SiO_2 *versus* Sc. Geochemical data for CMA and LGP from Deckart *et al*. (2010) and for LGP* from Cornejo and Mahood (1997). Symbols as in figure 4.

from the rest of the LGP/LGP* samples. They are also very different compared with the CAI sample. As well it has to be outlined that the low amount of MADSB samples are not statistically representative but indicate tendencies which have to be confirmed by a greater data set and a more detailed investigation.

5. Discussion

The petrographic, and especially geochemical analyses of the collected MADSB samples indicate that GD-16 (taken closest to the Cerro Mesón Alto Massif) and GD-19, GD-20 and GD-21 samples are generally more similar to CMA samples, whereas GD-13, taken closest to the LGP pluton and in the area interpreted as till deposits by Ormeño (2007) where rare and poorly polished blocks were recognized, seems to be more similar to LGP. All samples are visibly distinct from CAI.

According to these results and field observations, the Mesón Alto deposit seems to have been generated on the north-western slope of the Cerro Mesón Alto Massif (5,257 m a.s.l.), where the Cerro Mesón Alto monzogranite intrusive and andesitic rocks of Abanico

Formation crop out. The deposit shows similar lithologies in the blocks found on its surface. However, the deposit reaches 4.5 km^3 in volume (Marangunic and Thiele, 1971; Antinao and Gosse, 2009), which seems to be larger than the proposed source area (Fig. 3a). Meanwhile, sediments of likely glacial origin are recognized at the edges of the deposit. We suggest that the Mesón Alto is a composite deposit, where the landslide deposits lie on the top of an older glacial moraine at the confluence of the Yeso Valley with the Laguna Negra Lake. Ormeño (2007) found Last Glacial Maximum moraine deposits along the Yeso Valley down to the confluence with the Maipo River near the town of San Gabriel, thus the presence of Late Pleistocene moraines in the study area can be supported. However, the volume of the Mesón Alto deposits is much larger than other moraines in the Laguna Negra, Yeso or Encañado valleys, as observed by Abele (1984), supporting the suggestion of a composite origin.

The glacial deposits may have functioned as a 'shock-absorber', preventing the distal flow of the avalanche from traveling upstream towards the mentioned valleys. Additionally, they would have slowed down the mass that only traveled 4-7 km downstream the valley (travel distance, L); a short trip for the estimated enormous volume and the vertical distance from the landslide crown (H), of over 2,000 to 2,500 m. This results in a travel angle (H/L) of 0.3 to over 0.6, which is high for a landslide of this volume according to worldwide observations (Hutchinson, 1988; Cruden and Varnes, 1996), for which a H/L below 0.4 would be expected. Part of the avalanche could as well have been stopped by the presence of rock outcrops of andesitic lithologies in the SW sector of the deposit, between the Encañado and Laguna Negra lakes.

These preliminary results point to a variable origin of the entire deposit which could be described as a composite deposit of volcanic, plus CMA and to a lesser extent LGP intrusive lithologies, in addition to glacial material at the bottom and edges of the deposit. This result could possibly explain the gravimetrically estimated thickness of up to about 400 m accumulated chaotic material of the Mesón Alto deposit (Marangunic and Thiele, 1971). This interpretation is also supported by the at least 300 m water depth of the Laguna Negra Lake (Aguas Andinas, personal comunication, 2012) and the Antinao and Gosse (2009) dating of surface blocks, which coincide with similar rock slide dates in Portillo, Aconcagua Valley (32.8°S, Welkner *et al*., 2010) that may suggest high landslide activity between 4 and 5 ka in the region.

6. Conclusion

Field observations combined with laboratory sample analyses of five collected samples from the surface of the Mesón Alto deposit point to the Cerro Mesón Alto (CMA) for their origin. Thin section properties of all deposit samples compared with plutonic intrusions of the study area generally classifies them between the La Gloria Pluton (LGP/LGP*) and CMA granitoids, but dissociate them from the Cerro Aparejo Intrusion (CAI) characteristics. Major and trace element geochemistry supports this evidence and locate the data of the collected samples closer to CMA than to the entire LGP data set (Deckart *et al*., 2010; Cornejo and Mahood, 1997).

Considering these results, it is suggested that the most probable origin and depositional process of these surface blocks is related to a landslide that originated in the Cerro Mesón Alto Massif and travelled in an ESE to WNW direction. The glacial deposits now found on the deposit edges served as a natural barrier and stopped the rock avalanche from the Cerro Mesón Alto Massif at that point.

In summary, the analysis of surface samples suggests that these came from the Cerro Mesón Alto Massif and the probable origin of the deposit in the Yeso Valley is a megalandslide deposited on top of glacial moraines. Interpretation of large volume landslides such as the Mesón Alto along with investigation of active tectonics is a key issue for hazard assessment in this strategic mountain region of the central Andes as well as for improving the geomorphological understanding of the region.

Acknowledgements

Field work was supported by the Department of Geology at the Universidad de Chile through its Engineering Geology and Natural Hazards Program and by a professor interchange grant of the Cuyo National University to S. Moreiras. The authors would like to thank J. Martínez, Department of Geology, for geochemical analyses of the five collected blocks and CAI sample. M. Lara helped with the preparation of figure 2. We are grateful for the field trip assistance and manuscript discussions with L. Iturrizaga.

The authors especially thank the Aguas Andinas water company for allowing access to its premises in the study area. The authors also acknowledge the constructive comments from A. Fock and one anonymous reviewer along with the language verification from J. Le Roux.

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Manuscript received: October 30, 2012; revised/accepted: July 05, 2013; available online: July 08, 2013.