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UNIVERSIDAD INDUSTRIAL DE GEOLOGIA

STRUCTURAL EVIDENCE OF CALDERA COLLAPSE RELATED TO THE COMPLEX OF DOMES OF IZA, BOYACÁ

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XVI CONGRESO COLOMBIANO DE GEOLOGÍA
III SIMPOSIO DE EXPLORADORES
Geología, Sociedad y Territorio

INTRODUCTION

Volcanic collapse caldera is defined as a volcanic depression resulting a collapse of the roof of the magma chamber due to the faulting generated during an intrusion and the following degassification. Volcanic calderas present diameters between 1 to several tenth of kilometers and elliptical shape. In the Iza region in Boyacá department (Figure 1) Ulloa et al., (2001), Monsalve et al. (2011) reported the volcanic body of Iza corresponding to ascending pulses of rhyodacitic to rhyolitic magma, aged 2.1 - 2.5 ma. According to Cepeda and Pardo (2004) and Pardo (2004), the age of the Paipa dome, using the K / Ar and Ar / Ar methods, is 2.5 Ma +/- 0.06 . This study presents new geological evidences consinting in concerntric normal faults arround the volcanic dome of Iza, which clearly indicates the existence of a volcanic caldera that affected the adjacent Cretaceous units.

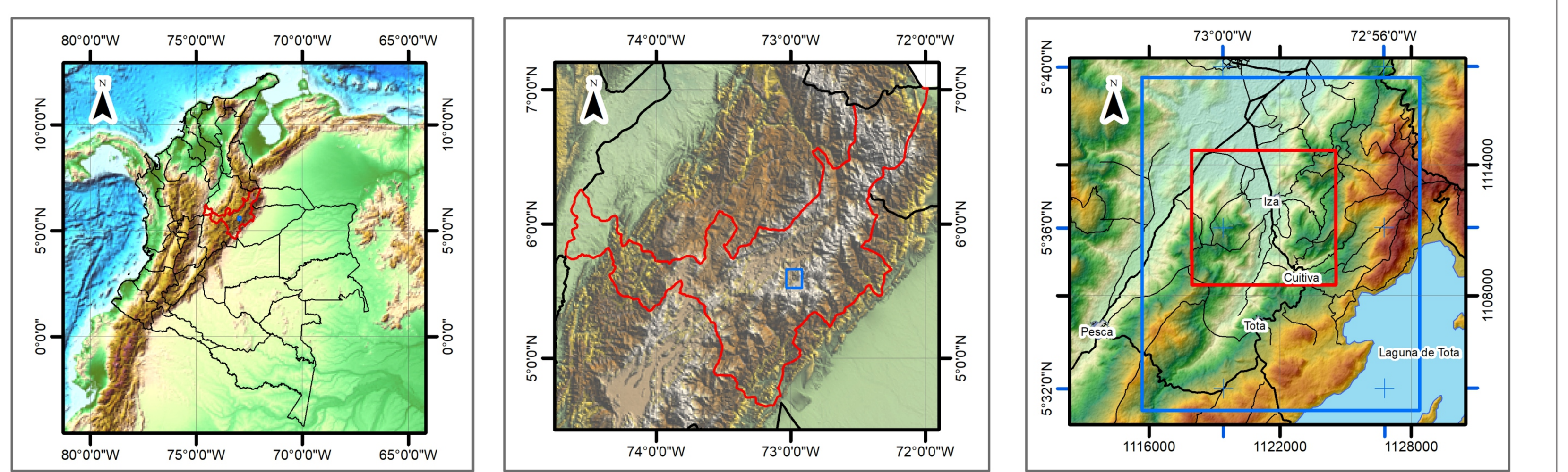


Figure 1. Location map of the study area of Iza, Boyacá.

METHODOLOGY

The research carried out in the municipality of Iza, Boyacá was based on data collection directly in the field, by means of control points in places where the rock was recently exposed, for example quarries and newly formed natural outcrops. With the use of the Handy GPS application (free) the location northing, easting, altitude was obtained to locate the point in the topographic map; the lithologies of each outcrop was identified and the relationships between them, including contacts and faults in order to update the cartography of the area. In addition to this, it was carried out the structural data acquisition of joints, plane of displacement of the faults, measurement of fault grooves taking into account the plane of displacement of the block in which was located the groove, pitch, plunge and azimuth of plunge and stratification planes (S0). With the information obtained in the field, the data processing was carried out using Tectonics FP (Reiter and Acs, 2000) and Stereonet.exe (Allmendinger et al., 2012) software, which are useful programs for the analysis of the spatial data orientation, through representation in Rose Diagrams, Contours and Equal-area pole plots. Photographs were also taken of the outcrop and the most representative samples of each rock type were chosen for further chemical analyzes. Finally, satellite images of different sources and types were analyzed for remote sensing with SENTINEL 2A images and Digital Elevation Models (DEM) of the Alos Palsar satellite.

THEORETICAL STUDY

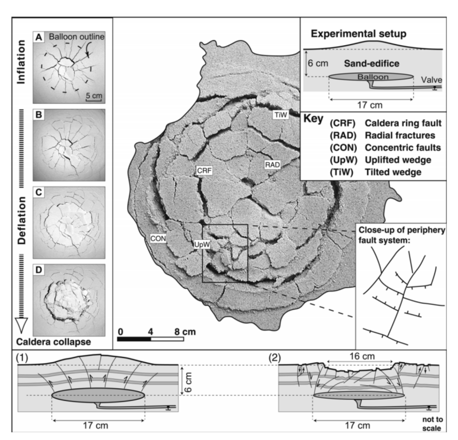
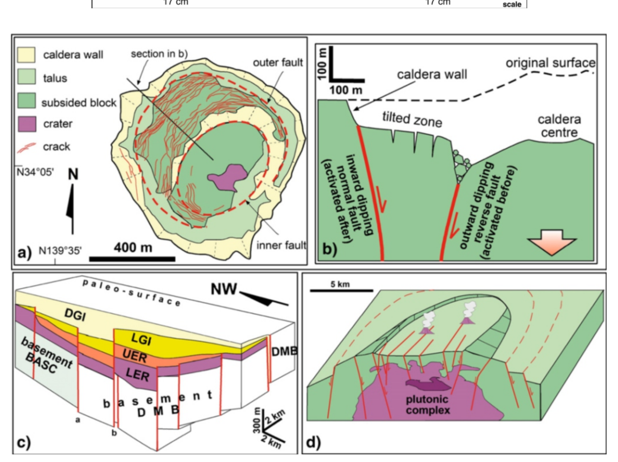
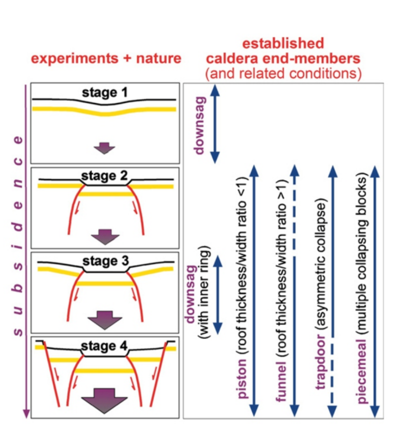


Figure 2. Experimental setup and results. Inset top right shows initial experimental construction prior to chamber inflation. Inset left shows photographs taken from above experimental setup after (A) inflation, (B, C) subsequent moderate deflation, and (D) evacuation of ~75% of balloon volume. Center: Photograph of surface deformation after cyclic inflation and deflation, projected onto outlines of Gran Canaria. Inset lower right: Close-up of complex fault interplay in periphery of produced caldera structure. Bottom inset: Cross sections of characteristic structures that form during balloon inflation (1) and subsequent balloon evacuation (2). Taken from (Troll et al., 2002).



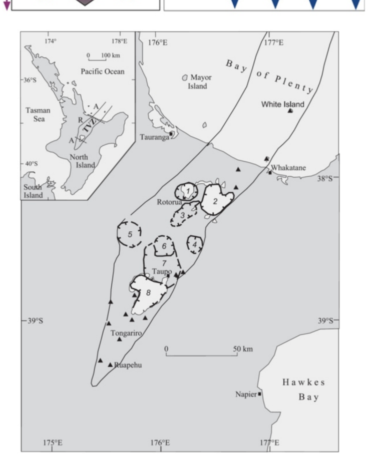
The geologic data collected on active and eroded calderas so far has only revealed end-member varieties (nested structures, piecemeals, trapdoors and downsag structures) superimposing over the classic piston-like scheme, consistent with recent reviews (Lipman, 1997; Cole et al., 2005). These types suggest an apparent complexity and the lack of a single, simple collapse model. Moreover, there is still fragmented or poor information on the location, geometry and kinematics of the main caldera structures and how these develop. (Acocella, 2007).

Fig 3.Examples of geological data on calderas. Map (a) and section (b) view of Miyakejima caldera, Japan, formed in 2000, bordered by reverse faults (formed first) and normal faults (formed later) (modified after Geshi et al., 2002). (c) Schematic structure of Glencoe caldera, England, and its main units, with a piecemeal-like structure (modified after Moore and Kokelaar, 1998). (d) Schematic reconstruction of the Archean Hunter Mine Group caldera, Canada, with inward dipping normal faults and outward dipping reverse faults (modified after Mueller and Mortensen, 2002). Taken from (Acocella, 2007).



The underpressure experiments and their comparison with calderas worldwide suggest an original revision of the structure, development and relationships of the established caldera types: downsag, piston-type, funnel, trapdoor and piecemeal (Lipman, 1997; Cole et al., 2005). In fact, the consistency among experiments and nature suggests that the architecture and development of the caldera end-members described in the literature may be contextualised within a subsidence continuum, in which the established caldera types are related to contributory factors (roof aspect ratio, symmetries, pre-existing faults; (Acocella, 2006).

Fig 4. Evolution of natural calderas geometries, summarized in 4 stages from a combination of experimental data and actual examples. To the right, caldera end-members (Lipman, 1997; Cole et al., 2005) and related conditions to form. Taken from (Acocella, 2007).



Rhyolitic calderas are associated with the largest volume pyroclastic deposits recorded and are usually huge collapse depressions. The calderas that form are usually >10 km in diameter and subsidence of the caldera floor is regularly >1 km. After collapse, resurgence may occur, in which the central part of the caldera becomes uplifted as a structural dome. This may be due to the upward resurgence of magma in the underlying magma chamber or post- caldera sill emplacement and often leads to further lava extrusion.

Fig. 5. Schematic map of the Taupo Volcanic Zone (TVZ), New Zealand, showing location of the rhyolitic calderas and caldera complexes. 1=Rotorua, 2=Okataina, 3=Kapenga, 4=Reporoa, 5=Mangakino, 6=Maroa, 7=Whakamaru, 8=Taupo. After Wilson et al. (1995). Triangles represent andesite–dacite volcanoes. Inset: A=Andesite dominated part of TVZ; R=Rhyolite dominated part of TVZ. Taken from (Cole et al., 2005).

EXPERIMENTAL STUDY

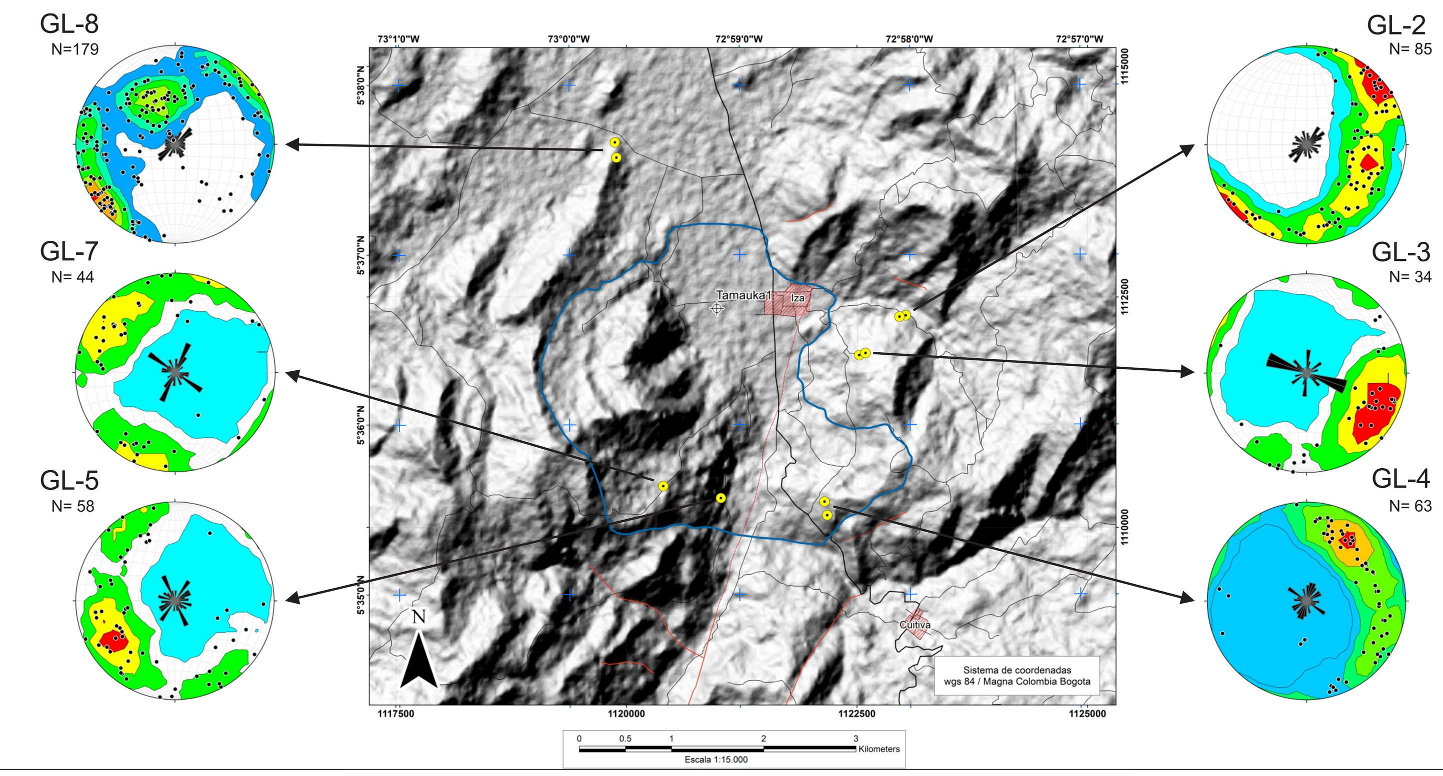


Figure 6. Hillshade showing the limit of the caldera collapse related to the complex of domes of Iza, Boyacá. Equal-area pole plots (n= 10 - 179 number of data) represent joints orientations at given locality with radial and concentric trends throughout caldera periphery.

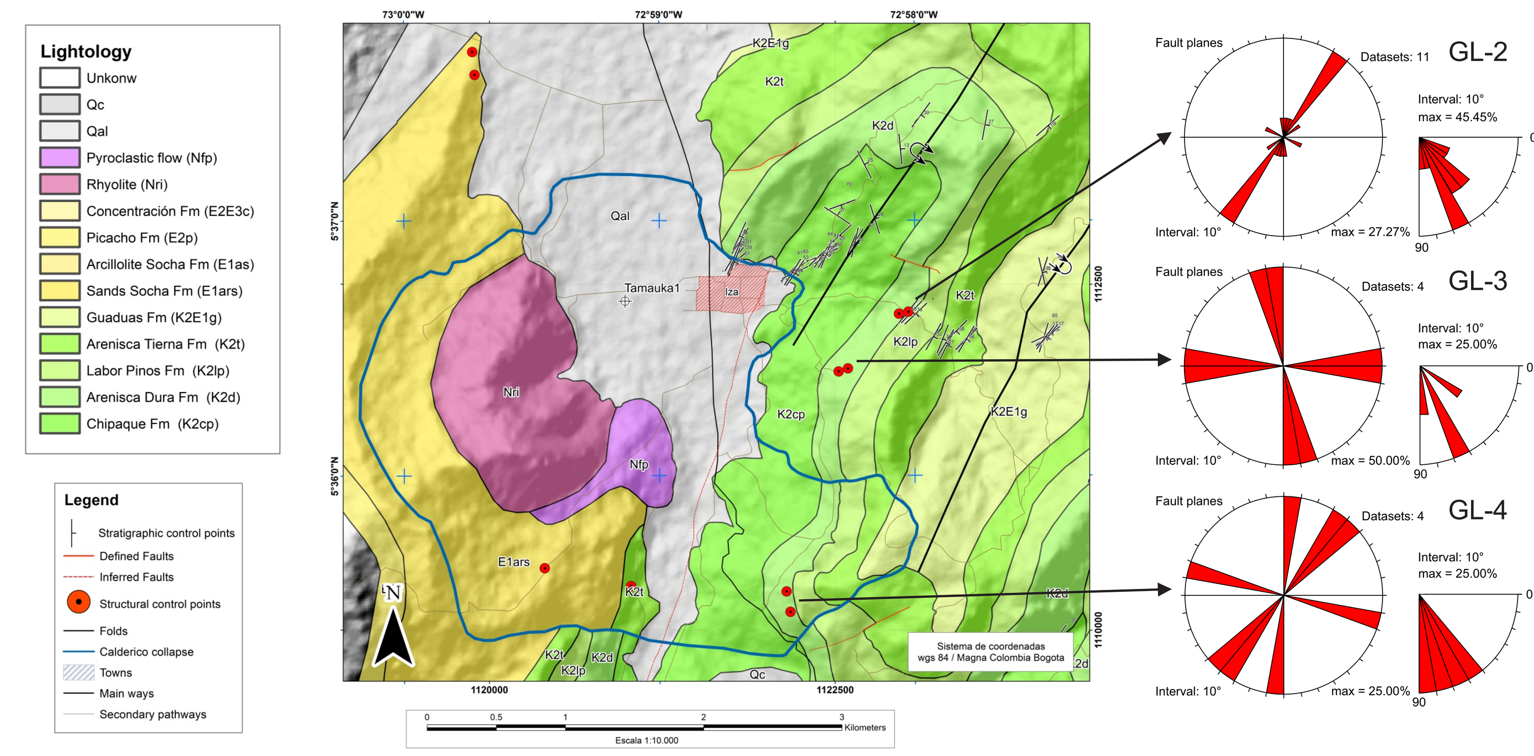


Figure 7. Geological map showing the sedimentary units related to the boundary of the caldera collapse related to the complex of domes of Iza, Boyacá. Strike and Dip measurements of planes with fault grooves in the different geological units that appear in the area, in the inclinations of the planes max = 45.45%. Produced by the authors, with the location of stratigraphic and structural control data carried out in the field.

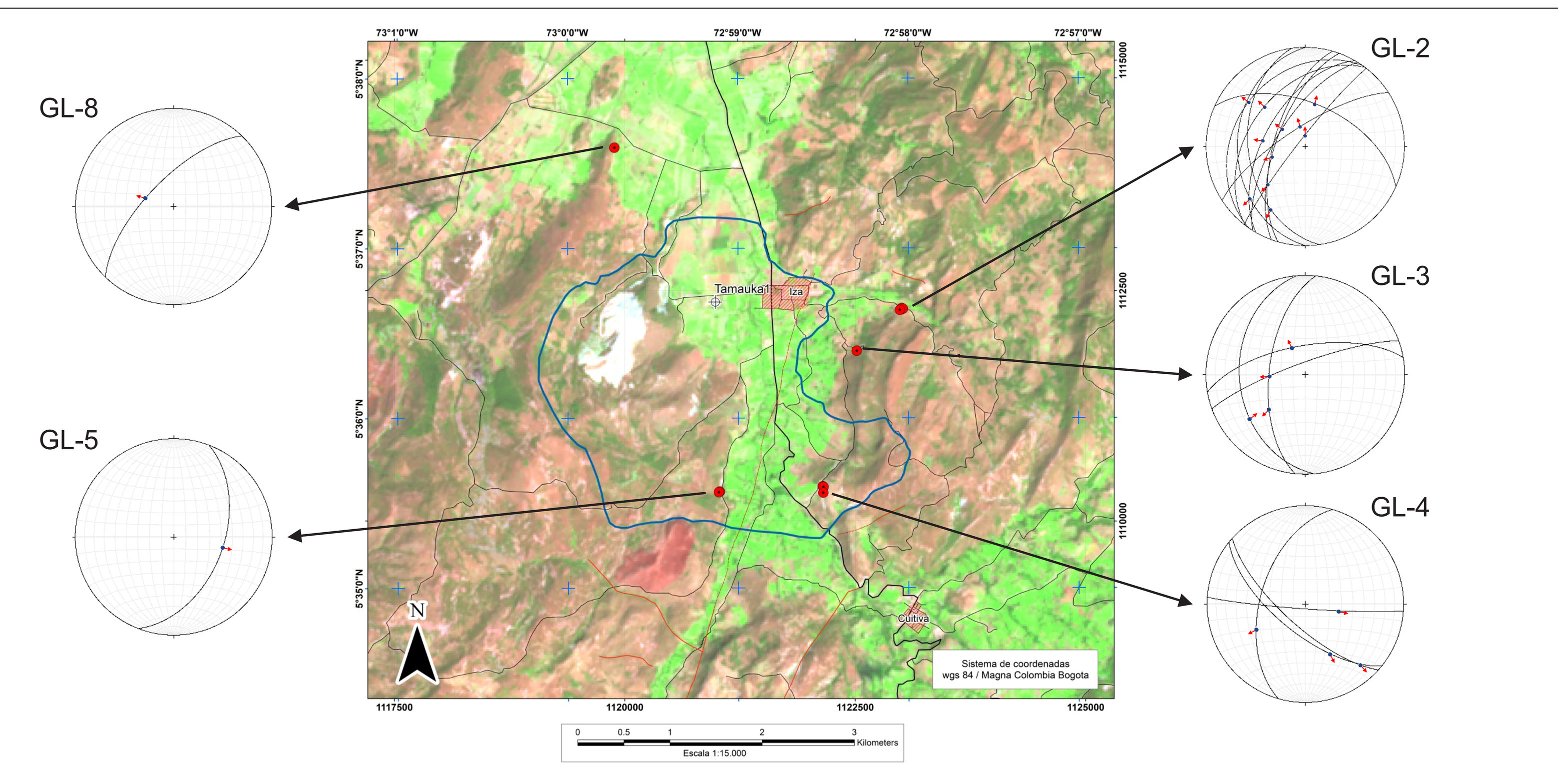


Figure 8. Multispectral image of the sensor SENTINEL 2A with a combination of bands 12 8A 4 (SWIR) that highlights the features of the terrain and allows evidence of regional structures.

RESULTS

The caldera collapse in the surrounding area of the rhyodacitic-rhyolitic dome complex of Iza was observed with diameters of 2 kilometers (see geological map and figure 6). This event occurred probably after the great eruption that formed the majority of these domes, and before the explosive exogenic dome described by Monsalve et al. (2011), located in the west part of the main dome named "Alto de Vita". The characteristic conic geomorphology of the domes, the presence of glass, the pyroclastic materials (Los Naranjos) 6 km NW of Iza, described by Schonwalder (2006) and the pyroclastic flow formed by the collapse of the explosive dome, confirm the exogenous genesis of the Iza complex domes. The cretaceous units Turonian to Oligocene (Chipaque, Arenisca Dura, Labor-Los Pinos, Arenisca Tierna, Guaduas, Arenisca de Socha, Lodolitas de Socha and Picacho Formations, described by Ulloa et al. (2001), Guarín (2011), among others), was affected by the emplazament and extrusion of the magma that formed the domes and the caldera collapse. The evidence of the caldera collapse are presented in the figures 7, 8 and 9, some of which presented distensive pattern with normal fault and decimetrics and metrics graben structures, pattern observed in different places inside of the caldera collapse, this pattern was not present outside of the caldera collapse area. A caldera collapse event and its delimitation contributes to the identification of surface thermal anomalies, like hydrothermal point "El Batan" such anomalies are located on the external rim of the caldera collapse (72° 59' 3.95" W, 5° 35' 14.02" N), and correlated with the high permeability zones generated by the normal faults associated with caldera collapse.

EXPERIMENTAL STUDY

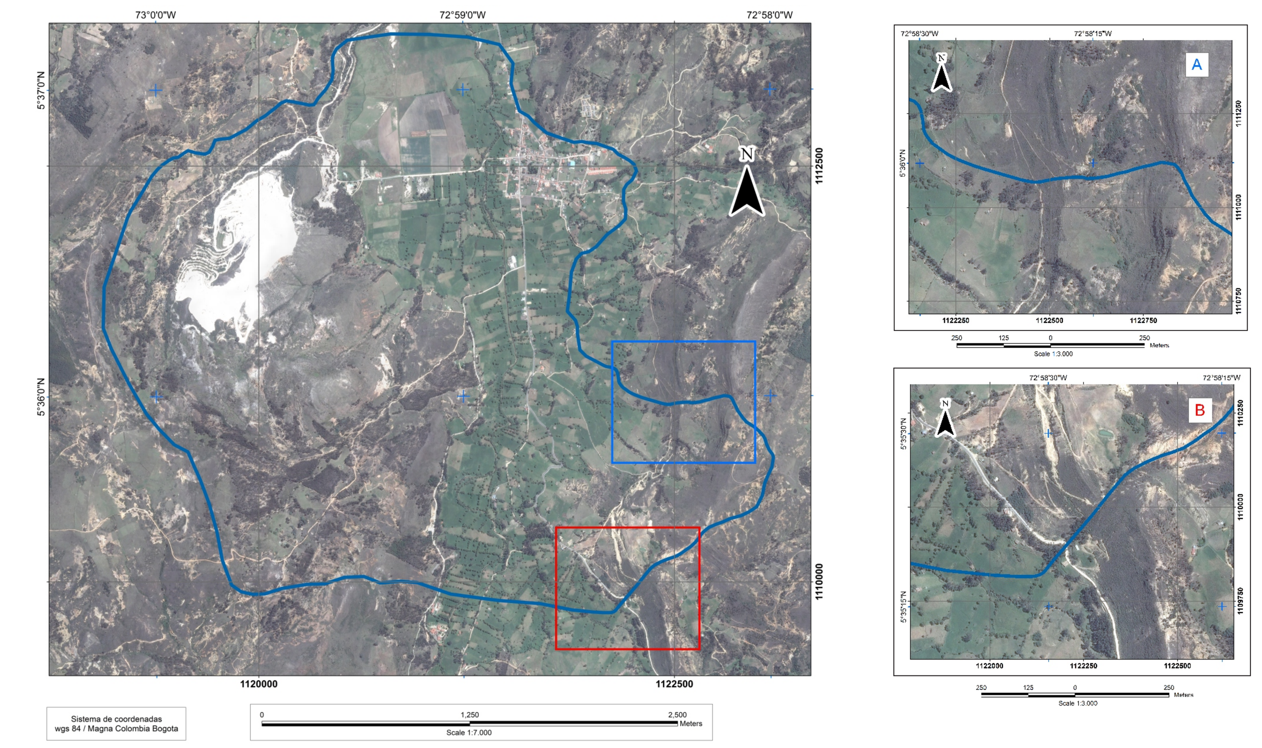


Figure 9. Orthoimage that shows the spatial distribution of the caldera collapse and presents the detail **Figure 9A** and **Figure 9B** of two zones where it can be seen a tilting in the present lithologies.

Figure 10. Photography showing normal fault affecting ADF "Arenisca dura" Formation in the outcrop GL2, 2.8 km East of the "Alto de Vita" rhyodacitic dome. West block down inside the volcanic caldera.

Figure 11. Photography showing normal fault and lateral movement product of calderic collapse, 0.92 km South of the "Alto de Vita" rhyodacitic dome. Block down "Guaduas" Formation inside the volcanic caldera.

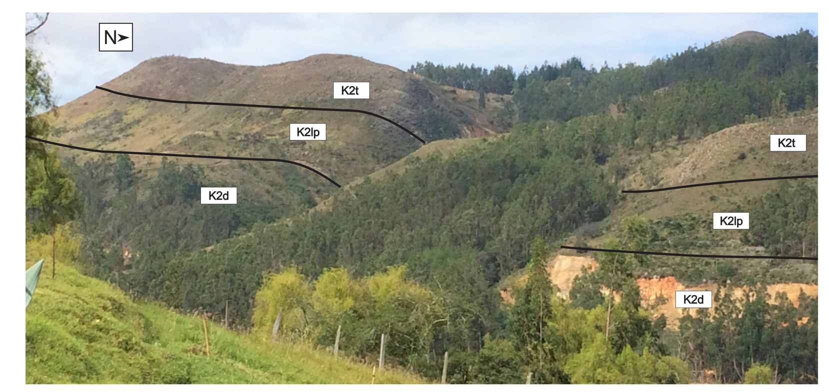


Figure 12. Photography showing normal fault, 1.3 km south of the "Alto de Vita" rhyodacitic dome, North block down inside the volcanic caldera, center and right of the photography.

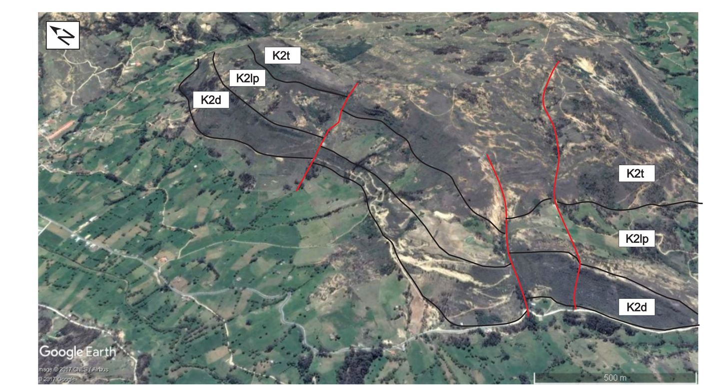


Figure 13. Red lines indicates normals faults displacement at the edges of the volcanic caldera in Iza. Image taken from Google Earth.

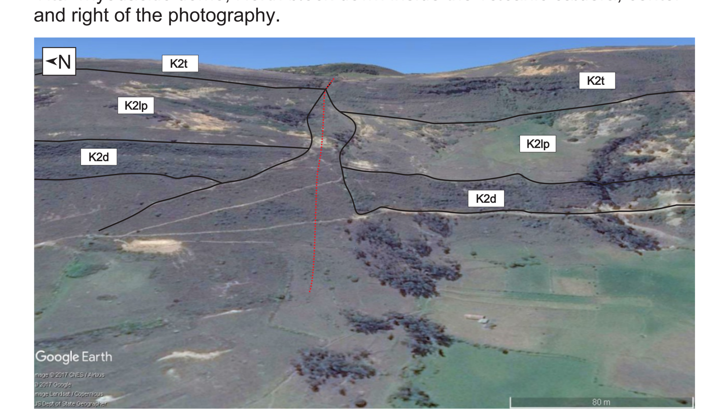


Figure 14. Frontal view of Figure 9A shows a normal fault, the block located to the south falls with respect to the block located to the north, right and left of the image respectively. Image taken from the Google Earth application

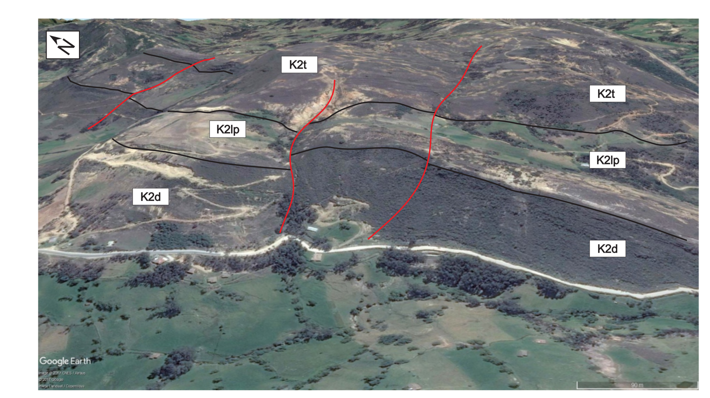


Figure 15. Frontal view of Figure 9B shows Red lines indicates normals faults displacement at the edges of the volcanic caldera in Iza.Image taken from the Google Earth application

CONCLUSIONS

The results obtained in the satellite images analyzed for remote sensing with SENTINEL 2A images and Digital Elevation Models (DEM) of the Alos Palsar satellite, the structural data acquisition of joints, and the data processing that was carried out using Tectonics FP (Reiter and Acs, 2000) and Stereonet.exe (Allmendinger et al., 2012) software, which resulted in the analysis of the spatial data orientation, through representation in Rose Diagrams, Contours and Equal-area pole plots that represent joint, faults and stress orientations with radial and concentric trends throughout caldera periphery, allow to verify the existence of a caldera collapse in the surrounding area of the rhyodacitic-rhyolitic dome complex of Iza, after the event that formed the majority of these domes, including the explosive dome of the west part of the main dome described by Monsalve et al. (2011). This event affected the Upper Cretaceous and Paleogene sedimentary units (Chipaque, Arenisca Dura and Plaeners, Labor and Los Pinos, Arenisca Tierna, Guaduas, and Socha Inferior Formations reported by Ulloa et al., 2001 and Guarín, 2011). A caldera collapse event and its delimitation contributes to the identification of surface thermal anomalies and the correlation of such anomalies with the high permeability zones generated by the faults associated with caldera collapse, for example, hydrothermal point "el Batan", such anomalies are located on the external rim of the calderic collapse (72°59´3.949"W, 5°35´14.028´´N).

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