Explanatory notes: Geological Map of Colombia

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Abstract

The GMC summarizes the superficial geological information of the Colombian territory. It was produced mainly by integration and simplification of the 1:100 000 scale geological sheets published by the CGS. Harmonization was controlled using remote sensing imagery such as Landsat TM and radar, and shaded relief images generated with NASA SRTM DEM with 30 m resolution data. The units represented on the GMC were defined according to a mixed chronostratigraphic–lithostratigraphic classificatory scheme.

The GMC has been compiled using ArcGIS 9.3.1 and the data model was designed and integrated into a corporative File Geodatabase using Oracle 10g and ArcSDE 8.3 for handling the data.

The following are the novelties in the GMC 2015 edition: (i) 120 new geological maps at a scale of 1:100 000 published by CGS; (ii) updated official base map from IGAC with MAGNA coordinate system; (iii) updating with scientific papers published until October 2014; (iv) "Radiometric dating catalog of Colombia in ArcGIS and Google Earth"; (v) improvements on trace and kinematics of faults with seismic data interpretations; (vi) harmonization with the geological maps of Perú and Brazil; (vii) adjustments in MGC´s interpretation as a result of feedback discussions during presentations in over 30 national and international meetings and events; (viii) Tectonic Framework of NW South America and the Caribbean with 2014 GPS vectors; (ix) new colors and ages of the International Chronostratigraphic Chart 2013, (x) chronostratigraphic unit patterns created with a font, and (xi) printed GMC and GAC as image overlays in Google Earth.

Key words: Geological map, GIS, chonostratigraphic units, terranes.

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Sheets 11, 12, 13,14, 15, 16, 17, 18, 19 and 20 of the Geological Atlas of Colombia at a scale of 1:500 000

Introduction

The Geological Map of Colombia is an ongoing project of the Colombian Geological Survey (CGS) that started in 2002. It is aimed to prepare a digital version of the geological map of the country. The 1st edition of the map was published in 2007 and a 2nd edition is released with this special edition. **11 new novelties of this new edition of the map will be differentiated with lower case roman numerals in parentheses.**

The main products of the project are: the 1:1 000 000 scale Geological Map of Colombia (GMC) and the 1:500 000 scale Geological Atlas of Colombia (GAC) which consist of 26 sheets. When we refer to the GMC, intrinsically we are referring to the GMC and the GAC.

A geological map is a scientific as well as teaching reference document that is displayed on a topographic map showing the distribution of rocks and superficial unconsolidated materials, as well as the structures that have deformed them. In order to show the age and composition of those geologic materials, colors and patterns are usually employed. To indicate the spatial orientation of geological structures (e. g., faults and folds), appropriate symbols are added to the map.

Besides to let the users to know the geology of the terrain at a designated place, a geological map allows the users to infer the distribution of the materials found at depth. In other words, a geological map is a representation of the geology of an area which has profound implications on many aspects, from the way in which the landscape evolves to the type of vegetation that best thrive there, from the availability of underground water to the occurrence of useful minerals, from the amount of displacement of fault in the terrain caused by an earthquake and associated landslides to the water contamination. From an academic point of view, a geologic map is a fundamental document because it provides information to interpret the evolution of the Earth. Therefore, this document is essential for all those interested in geosciences, the sustainable use of natural resources and the management of the environment, including in the latter the assessment of geological hazards.

The GMC is made from a compilation of regional geological maps and summarizes at a scale of 1 000 000 the geological information of the country surface. The bulk of this information is composed of the geological maps published by the CGS. For those areas where there was no map coverage available, unpublished maps from joint venture international projects were used, such as from the oil industry or from geological consultancy groups. However, due to the heterogeneous nature of the Colombian landscape, including inaccessible places of high relief and/or covered by dense tropical forest, considerable gaps remained. Those gaps were filled with the interpretation from remote sensing imagery. These field circumstances and changes in government policies with respect to the objectives of geological mapping have had implications on the quality and accuracy of the compiled information. Consequently, current knowledge of the geology of Colombia is displayed by the GMC.

For using the GMC 2015 it is important to note that it includes geological maps published until December 2013 and geological data published until October 2014.

History

The GMC project was conceived under the initiative of the Sub–directorate of Geological Exploration of CGS in the first months of 2002. It was aimed to review and update the Digital Geological Atlas of Colombia (DGAC), version 1.1 (*cf.* Forero *et al*., 1997), a task scheduled for 8 months. However, DGAC had been compiled on a 1:500 000 scale topographic base map taken from the Colombian Forest Map published by the Augustín Codazzi Geographical Institute (IGAC), which previously had many incorrect findings. But considering the fast advances in digital cartography, with its almost unlimited possibilities for scale change and georeferencing of maps as well as remote sensing images with decimeter precision, much improvement has been achieved in the geological mapping of Colombian territory. Instead of straight ahead reductions in scale, the geological features from maps published to larger scales were adjusted to this base map, resulting in a loss of accuracy. This inaccuracy invalidated any intent for updating the DGAC aimed at producing a map that takes advantage to the technological advances offered today by the Geographical Information System (GIS), which allows the optimization of the information available.

In view of the limitation of updating of the DGAC, the working group made the decision to prepare a completely new map integrating all regional geological sheets and quadrangles published. To reach this goal correctly, it would have been a mistake if we had not used the original topographic base maps of compiled sheets and quadrangles, because the publication of them required complete accuracy. The accuracy was needed for georeferencing in GIS faithfully. Faced with this new scope, it was impossible to fit the project into the original scheduled time–frame. This time dilemma was due, in part, to the additional compilation tasks and the labour of synthesizing of the geological data by sheets and quadrangles. It was also necessary to review the updated geological literature, in order to solve the problems of interpretation that became evident during the map compilation and correlation work. Furthermore to afore mentioned, interpretation of remote sensor images for the areas that lacks information was made.

The decision of elaborate the GMC by integration of all information contained in geological map sheets and quadrangles was determined by the intrinsic availability of a 1:500 000 scale base map —as that was the scale of the DGAC map to be updated—. However, there was any integrated geographic database with the required scale. In 2003, a new Integrated Digital Model (MDI) was given to the CGS by IGAC —which did not adjust properly to the corresponding information in the geological map sheets and quadrangles hence it was rejected as a base map— and it was also given the shaded relief images elaborated on basis of Digital Elevation Model (DEM) of the National Aeronautics and Space Administration's (NASA) Shuttle Radar Topography Mission (SRTM) radar interferometry data distributed by the United States Geological Survey's (USGS) EROS Data Center (USGS, 2002), with a resolution of 90 m which allowed adjust the GMC in areas where the base map did have not good accuracy.

By October 2006, IGAC provided to CGS a 1:500 000 scale base map prepared from the NASA SRTM DEM radar interferometric data (USGS, 2004) with 30 m resolution, which finally was adopted as the base map of the GMC. Taking into account the thematic character of the GMC, we established a **visual hierarchy** because it was clear that the geological information had the major importance. Therefore, during the adaptation of the base map, it was necessary to reduce the complexity of the information and change its styles.

Data compilation

Considering that the GMC project is essentially a work of compilation and synthesis, it is worth pointing out that the format of the regional geological maps published by the CGS has changed considerably over the years, in concordance with the formats of the IGAC's topographic base maps. The first maps were quadrangles (60 × 80 km) published at a scale of 1:200 000. But, the scale of the publication of the quadrangles changed to 1:100 000 at the end of the 1960´s (making the bigger quadrangle maps difficult to manage). Since 1976, this 1:100 000 quadrangles were split into two sheets, giving rise to the 60 × 40 km and 1:100 000 sheets in use today.

On the other hand, to reduce the area deformation of these maps elaborated in conformal transverse Mercator projection, the territory of the country was divided according to bands, each of 3° of longitude centered on the meridians of 68° 04' 51,3" W, 71° 04' 51,3" W, 74° 04' 51,3" W and 77° 04' 51,3" W. For the assignment of a Plane Coordinate System, the intersections of these meridians with the parallel of 4° 35' 56,57" N were used in each case, and a value of 1 000 000 N and 1 000 000 E was given to each point of those intersections. However, because the map sheets of 60 km of width did not fit precisely within these band zones, at both extremes there are maps of 47 × 40 km. Since 2005, with the adoption of the new National Geocentric Reference Frame (MAGNA) used in the CGS, the values of the origin of the plane coordinate changed to the meridians 68° 04' 39,0285" W, 71° 04' 39,0285" W, 74° 04' 39,0285" W and 77° 04' 9,0285" W, and the north parallel 4° 35' 46,3215" N.

In some places, geological maps compiled for the GMC represent the only data available, they include pioneering works as well as compilations of cartographic information obtained from oil companies published in quadrangles at scales of 1:200 000.

As a result of the joint venture project No. 514–L–030 of the International Agency for Development (IAD) carried out between CGS and the USGS, there were published many 1:100 000 scale sheets (Ward *et al*., 1977a; 1977b; Feininger *et al*., 1975; Álvarez *et al*., 1975, and Tschanz *et al*., 1969) which established standards of mapping that were temporarily adopted in the cartographic practices of the CGS.

The GMC includes all sheets at a scale of 1:100 000 published until December 2013 by the CGS and covering the 57 % of the Colombian territory. It is fair to mention that some of these sheets were adjusted by the IGAC`s 1:100 000 base maps from geological maps which were pioneer works such as those of Grosse (1926) that was elaborated using topographic bases made during geological field works.

For the eastern poorly accessible half of the country, such as the Amazonas and Orinoquia region, the available information is less accurate, because there was no complete survey of the area. On one hand, the geological information published for the Amazonas is at a scale of 1:500 000 and is based on the interpretation of radar images complemented by field reconnaissance (Galvis *et al*., 1979). And on the second hand, the Orinoquia region with poor geological mapping at a scale of 1:100 000 was interpreted from imagery by the staff of the GMC. This task of interpreting direct remote sensor images was also performed in several areas where information gaps existed, such as the Urabá region of the Chocó Department, the western flank of the Western Cordillera in the Cauca and Nariño departments, and serranía de San Lucas. Also, for other regions with difficult access, like the Llanos Foothills of the Eastern Cordillera (Geophoto Services Inc., 1969) and serranía de la Macarena, were used unpublished photogeological maps at scales of 1:50 000; (Geotec, 1971a, 1971b, 1971c, 1971d, 1971e, 1971f and 1971g).

Cartographic sources

Appendix 1 shows in white the geological maps at different scales compiled for the GMC 2007, and (i) in yellow the 120 integrated geological maps for GMC 2015. Numbers in the Appendix 1 indicate the bibliographic references that are listed following the graph.

Method of map preparation

The principal tool used in the elaboration of the GMC was ESRI^{TM}'s ArcMap–ArcGIS 9.3.1 desktop software. The procedure used to perform the GMC was to convert the layers of lithostratigraphic units, faults and folds in E00 format (ESRI ArcInfo interchange file), coverage (ArcInfo) and Geodatabase (ArcGIS) to shapefile. Then we proceeded to convert the shapefiles from Bogotá datum to MAGNA datum, which is the official coordinate system for Colombia according to Resolution No. 068 of January 28th of 2005, and (ii) it was adopted as unique official datum for Colombia. The migration process was performed according to the regional processing parameters to migrate georeferenced information from Bogotá datum to MAGNA system established by the IGAC (2004). It is noteworthy that the MAGNA reference system has an associated ellipsoid corresponding to the GRS80 (Global Reference System 1980), equivalent to WGS84 (World Geodetic System 1984).

Once we had the shapefiles in MAGNA, they were generalized to 1:500 000 scale for the GAC and to 1:1 M scale for the GMC. Lastly, the shapefiles were migrated to a Feature Dataset incorporated in a File Geodatabase containing the integrated geological maps named **agc2015.gdb** for GAC and **gmc2015.gdb** for GMC.

One aspect of the process of data integration that required special attention was the frequency of poor matching of the geological harmonization across the sheet boundaries. The ArcMap–ArcGIS tools allowed the display, superimposition and thus the simultaneous comparison of the compiled cartographic information with remote sensing imagery; while shaded relief images facilitated the correct positioning of mapped geological units and structures. Those tools improved matching adjacent map sheets. In order to control the process of map joining and correlation, there were used the ortho–images of Synthetic Aperture Radar SAR–1 (INTERA from 1992), Landsat Tematic Mapper (TM) imagery and the shaded relief images. These shaded relief images in combination with Landsat TM imagery accentuated the geomorphologic features, making possible to achieve better quality control of the compiled data.

Shaded relief images were generated in ArcScene 9.3.1 with the Hillshade tool from NASA SRTM DEM (USGS, 2004). As Colombian topographic features has mainly N–NE direction, it was used a combination of two shaded relief images (grouped), the first one created with an azimuth of 45°, an altitude of 45° and a transparency of 50 % superimposed, and the second one was created with an azimuth of 315°, an altitude of 45° and without transparency. This configuration allows an excellent visualization of geomorphological features for the majority of the Colombian territory.

In sectors where there was no correspondence between physiographic features and distribution of rock units and structures indicated in the maps, the information was corrected according to the shaded relief images or Landsat TM imagery. During the integration and synthesis of the compiled data, editing was carried out in such way that the best possible display of the information would be obtained at 1:500 000 and 1:1 000 000 scales, which are the publication scales of the GAC and GMC, respectively.

In order to keep updated the GMC, since the beginning of the project all the geological information related to the Colombian geology published was reviewed, such as national and international scientific journals; books; undergraduate, master and doctorate theses; geology conference proceedings; reports produced by institutions such as the Hydrocarbons National Agency (ANH); unpublished reports of the CGS, and geological maps of neighboring countries. This information was stored in physical media for quick consultation, and the references were added to an EndNote X4 library. GMC 2007 included information published until December 2005, and (iii) GMC 2015 geological information published since December 2005 until October 2014, ending with the geochronological data of Martens *et al.* (2014).

All of these publications allowed to update the GMC on the following aspects:

1. Ages of igneous and metamorphic geological units of the map were updated using geochronological data, mainly ages $Ar^{40}–Ar^{39}$ and U–Pb (Sensitive High Resolution Ion Microprobe, SHRIMP and Laser Ablation–Inductively Coupled Plasma Mass Spectrometry, LA–ICP–MS) taken from the (iv) "Radiometric dating catalog of Colombia in ArcGIS and Google Earth" (Gómez *et al.*, 2015) made for this purpose. In this regard, the following publications were very useful: Priem *et al.* (1989), Restrepo Pace *et al.* (1997), Ordóñez Carmona (1997), Ordóñez Carmona (2001), Cordani *et al.* (2005), Vinasco *et al.* (2006), Cardona *et al.* (2010), González (2011), Leal Mejía (2011), Restrepo *et al.* (2011), Villagómez *et al.* (2011) and Martens *et al.* (2014). The Catalog is included as a Feature Dataset (named CataloDatacioRadiomeCol) in the GMC 2015 File Geodatabase.
2. (v) Structural and subsurface information helped to improve the definition of the type, nomenclature and traces of the faults included in the GMC 2015 (e. g., Barrero *et al.*, 1998; López & Barrero, 2003; Cortés, 2004, and Restrepo Pace *et al.*, 2004).
3. Ages of many sedimentary units were updated according to reports of macro and micropaleontological fossils (e. g., Grösser & Prössl, 1991; Prössl & Grösser, 1995; Angiolini *et al.*, 2003; Dueñas & Césari, 2005; Wesselingh *et al.*, 2006; Latrubesse *et al.*, 2010, and Arango *et al.*, 2011).
4. To make the Geological Terranes Map of Colombia, the geotectonic framework of many areas of Colombia was evaluated. It is highlighted the contributions of Etayo Serna *et al.* (1969), Kroonenberg (1982), Priem *et al.* (1989), Forero (1990), Toussaint (1993), Maya & González (1995), Ordóñez Carmona (1997), Nivia (1987), Kerr *et al.* (1997), Tassinari & Macambira (1999), Kerr *et al.* (2002), Ordóñez Carmona (2001), Sarmiento (2001), Gómez *et al.* (2003), Cordani *et al.* (2005), Gómez *et al.* (2005a, 2005b), Vinasco *et al.* (2006), Mora *et al.* (2009), Weber *et al.* (2009), Cardona *et al.* (2010), Horton *et al.* (2010), Parra *et al.* (2010), Weber *et al.* (2010), Villagómez *et al.* (2011), Leal Mejía (2011), Restrepo *et al.* (2011), Ibáñez Mejía *et al.* (2011), Bayona *et al.* (2012), Saylor *et al.* (2012) and Martens *et al.* 2014.

Currently, the Subcommission for South America of the Commission for the Geological Map of the World (CGMW) are undertaking the Geological and Mineral Resources Map of South America at a scale of 1:1 M under the leadership of Carlos SCHOBBENHAUS of the Geological Survey of Brazil (CPRM) and Jorge GÓMEZ TAPIAS from the CGS, and sponsored by the Iberoamerican Mining and Geology Surveys Association (ASGMI). In this context, in 2009 the geological surveys of Brazil, Colombia and Perú (IMGEMMET) began to prepare the geological sheets NA.–19, NB.–19 and SA.–19. For this purpose, three interdisciplinary workshops were carried out at the University of Tabatinga in Brazil from the 1st to the 2nd October 2009, from the 10th to the 11th August 2010, and from the 30th November to the 1st December 2011. One of the main results of those workshops was the harmonization of the geological maps of Brazil, Colombia and Perú. This task was achieved using both Geocover imagery from NASA, and Aeromagnetometry and Aerogamaspectrometry maps. (vi) Such information and feedback with the teams of Perú and Brazil was included in the GMC 2015.

Following the recommendation of McLelland (2006) that state: "Scientific explanations should always be made public, in print or either presented at scientific meetings", pointing out that the **evaluation** by the scientific community is the final part of the scientific method; the GMC has had extensive divulgation at universities, formal and informal events and national (e. g., Gómez *et al.*, 2005c; Gómez *et al.*, 2009, and Gómez & Montes, 2011) and international congresses (e. g., Gómez *et al.*, 2007; Gómez *et al.*, 2008, and Gómez *et al.*, 2012).

During the GMC divulgation important discussions and valuable contributions allowed to identify misallocated ages and misinterpretations of some units. (vii) Authors of the GMC have been agreed with all these contributions, due to the strength of the data (e. g. Triassic age of the metamorphic rocks of the Central cordillera, considered as pre–Ordovician in the GMC 2007), and so those contributions were corrected in the version released in 2015.

Finally, when difficulty was found in making a decision because of the ambiguity and antagonism of the data collected, **370 days of field work** has been made to many places around the country until October 2014. Those field works have helped to solve some of these geological problems identified, as well as to make decisions, to take samples for geochronology and to find new fossiliferous localities that have provided valuable data that is expected to be published in the coming years. In the same way, during the 14th Latin American **Geological Congress and 13th Colombian Geological Congress it was made the field excursion named Geological cross section of Colombian Andes at 4° of North Latitude (Villavicencio–Buenaventura),** held from 22th to 27th August 2011, and with the collaboration of Dr. Darío BARRERO LOZANO independent senior consulting geologist and Dr. Eduardo LÓPEZ RAMOS from Ecopetrol.

Philosophy and design of the GMC

In order to prepare the GMC, we developed our own specific methodology which reflects the characteristics and mapping history of Colombia complemented with elements of other geological surveys.

The GMC consists of 2 sheets. Sheet 1 is the map and sheet 2 is the map legend. The former contains, as its principal element, the geologic map. This map has representations of the offshore islands of Colombia; due to their far distance from the mainland and their small size, they are displayed as insets at a scale of 1:100 000 (Figure 1). Displayed in one inset are the corporate credits and author listing, and in another inset the Localization of Colombia in South America. In addition, there are diagrams that provide the reader with a better contextual understanding of the geology of Colombia. They are: a sketch of the Tectonic Framework of Northwestern South America and the Caribbean; the Colombian Physiographic Map, showing the location of the features frequently quoted in the geological description of the country, and Geological Terranes Geological of Colombia, a proposal made based on geological information compiled for the GMC and geochronological assessment carried out in the "Radiometric dating

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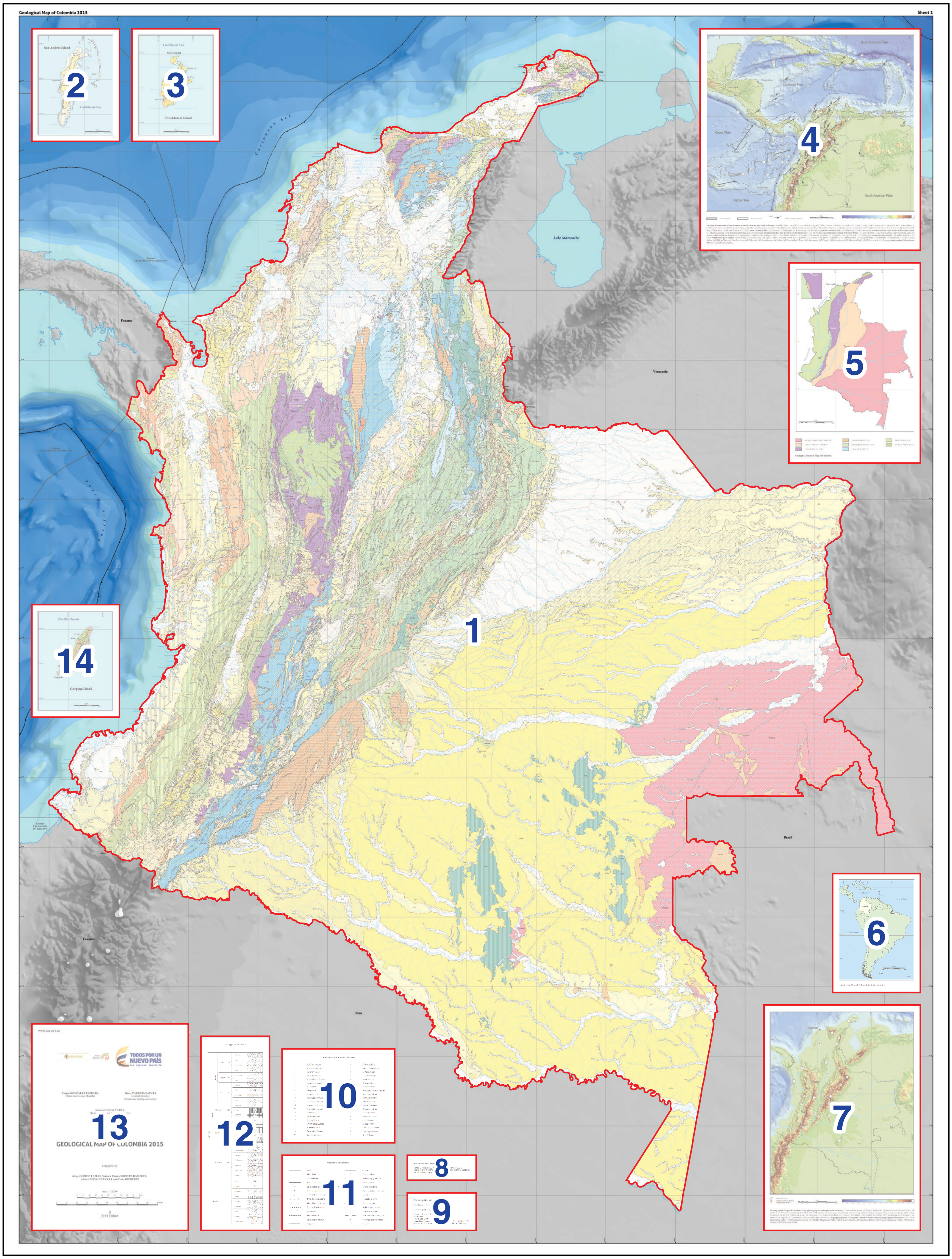
Figure 1. Geological Map of Colombia 2015, sheet 1 insets. (1) Geological Map of Colombia, (2) Geological Map of San Andrés, (3) Geological Map of Providencia, (4) Tectonic Framework of Northwestern South America and the Caribbean, (5) Geological Terranes Map of Colombia, (6) Localization Map of Colombia in South America, (7) Physiographic Map of Colombia, (8) suggested citation, (9) cartographic sources of the base map, (10) Quaternary volcanoes of Colombia, (11) geological conventions, (12) lithologic pattern chart, (13) credits and (14) Geological Map of Gorgona.


Geological Map of Colombia 2015
Sheet 1
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7
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10
11
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14
Lake Maracaibo
Venezuela
Panama
Ecuador
Peru
Brazil
San Andrés Island
Providencia Island
Gorgona Island
TODOS POR UN NUEVO PAÍS
GEOLOGICAL MAP OF COLOMBIA 2015
2015 Edition

catalog of Colombia in ArcGIS and Google Earth" (Gómez *et al.*, 2015). Finally, there are insets that display the conventions used in the map, which describe the structural elements and a list that displays the citations used for the Quaternary volcanoes (Figure 1).

Tectonic Framework of Northwestern South America and the Caribbean at a scale of 1:5 000 000 was performed on a DEM where major tectonic features were located in the Caribbean region and Colombia, the main folds and faults were taken from GMC 2015. Among the most relevant information compiled for the realization of this map were Hey (1977), Lonsdale & Klitgord (1978), Case *et al.* (1984), Adamek *et al.* (1988), Hardy (1991), Zamora & Litherland (1993), Meschede *et al.* (1998), Gutscher *et al.* (1999), Audemard *et al.* (2000), Barckhausen *et al.* (2001), MacMillan *et al.* (2004), Giunta *et al.* (2006) and Escuder Viruete *et al.* (2006). The values of the relative motion vectors of plates were taken from the GPS data from GEORED Project of the CGS (http://geored.sgc.gov.co/) and Protti *et al.* (2015). (viii) GPS vectors, updated to December 2014, were plotted considering the magnitude and azimuth. Data were compiled from 57 stations that belong to the International Terrestrial Reference Frame (ITRF) 2005.

Sheet 2 gives a description of the Chronostratigraphic Units (CU), accompanied by a brief description of the rock types and deposits (Figure 2). The elements containing these descriptions are organized according to their age of formation, with the more recent materials placed at the top of the sheet. In order to display this organization of elements, the International Chronostratigraphic Chart (ICC) (Figure 3) of the International Commission on Stratigraphy (ICS) (Cohen *et al.*, 2013) was reproduced on the left margin of the sheet. For a detailed description of the ICC see Gradstein *et al.* (2012).

These units which are represented on the map were defined according to a mixed chronostratigraphic–lithostratigraphic classification scheme that took into account 3 criteria: age, lithology and geological terrane.

In this classification scheme a distinction was made between rocks and unconsolidated deposits. The latter was subdivided according to type of deposit in: alluvium, terrace, alluvial fan, paludal, glacial, pyroclastic, dune, swamp and volcanoclastic. On the other hand, rocks were represented in accordance with their principal types in: igneous, metamorphic and sedimentary with volcaniclastic rocks as a separate type. Igneous rocks were differentiated both according to their composition (ultramafic, mafic, intermediate and felsic) and to their environment of formation (plutonic, hypabyssal and volcanic).

Metamorphic rocks were differentiated according to their grade of metamorphism into very low, low, medium, and high grade (*sensu* the Geological Map of South America from Schobbenhaus & Bellizia, 2001; and the International Map of Europe and Geological Map of Europe Adjacent Areas from Asch, 2005), and high pressure. An exception was made with the marbles due to their occurrence in several grades of metamorphism and economic importance.

For the sedimentary and volcanoclastic rocks the main environment of accumulation was indicated as marine, transitional or continental. Into transition environments were considered the delta plains, costal lagoons, intertidal plains and coastal fans. However, due to extent of the outcrops and to the map scale at which the information is displayed, some stratigraphic intervals had embraced diverse environments and so within the classification scheme it was necessary to create subdivisions that considered the union of various environments (continental–transitional, continental–transitional–marine and transitional–marine).

(ix) With respect to the colors used to indicate the age of the GMC's units, classification and values of Red, Green, Blue (RGB) were adopted from the Commission for the Geological Map of the World (Pellé, 2008). In order to improve the identification of the CU and the readability the map, a pattern was designed for each type and formation environment of rocks and deposits (Figure 4). Half of these were taken from FGDC (2006) that come by default in ArcGIS™ software. The other half was developed by the GMC´s team at the CGS (Figure 2). GMC and AGC patterns are the same, the only difference is the size. In this way, each CU is represented by a color, that represents its age and a pattern which corresponds to its lithology and by extension its formation environment.

(x) For better visualization, patterns were created in Corel Draw 14 and exported to a font named Tramado_MGC.TTF (True Type Font) loaded in ArcGIS to generate the pattern. This methodology was adapted from the Geologic Map of North America (Reed *et al.*, 2005a) and has the advantage that the display of the map in ArcGIS is faster, printing time map is reduced around 80 % and the map has a sharper graphics output, both in paper and in PDF format.

In addition, the CU was assigned with a code composed by the recommended notation for geochronologic units (Remane, 2000), separated by a hyphen from an acronym that shows the rock type and its formation environment. The main rock type is indicated by uppercase letters (M: metamorphic, VC: volcaniclastic, etc.) followed by lowercase letters that depicts its composition, metamorphic grade or depositional environment in accordance to whether it is igneous, metamorphic or sedimentary rock respectively (u: ultramafic, lg: lower grade of metamorphism, ct: continental–transitional). The following example illustrates this notation:

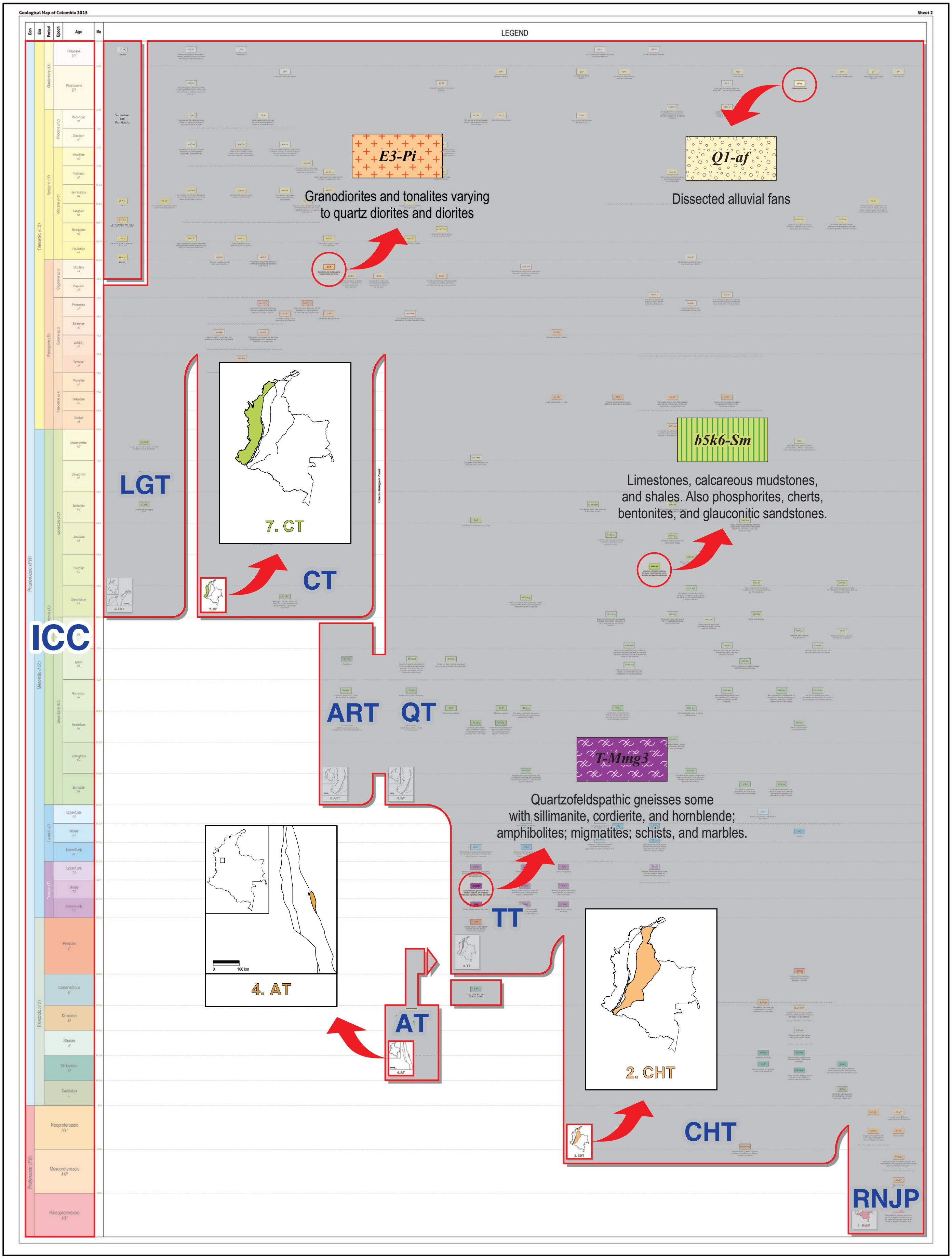
MP3NP1–Mhg3

Age + Lithology + Geological terrane

Stenian–Tonian   High–grade metamorphic rocks   Chibcha Terrane–CHT

Assignment of the age code was made in each case according to the existing knowledge of the CU actual geochronological age. In some cases, because of the uncertainty of available knowledge it was decided to assign a code of era for the CU (e. g. *PZ–Sm* corresponds to Paleozoic marine sedimentary rocks). When geochronological data allowed the precise definition of the rock age the assignment of the code was specified at the level of age (e. g., *b2–Vf* for felsic volcanic rocks of the Valanginian). When geochronological data indicated time intervals of rock ages, their limits were shown (e. g., *k5E1–Stm* indicates Campanian to Paleocene age sedimentary rocks of transitional and marine environments). When rock age data was doubtful, uncertainty was expressed with question marks (e. g., *b5?k6–Sctm*, it suggests that we deal with sedimentary rocks accumulated in continental, transitional and marine environments between the Maastrichtian and possibly the Aptian; *n1?n5?–VCc* stands for volcaniclastic rocks accumulated in continental environments, possibly between the Aquitanian and Tortonian).

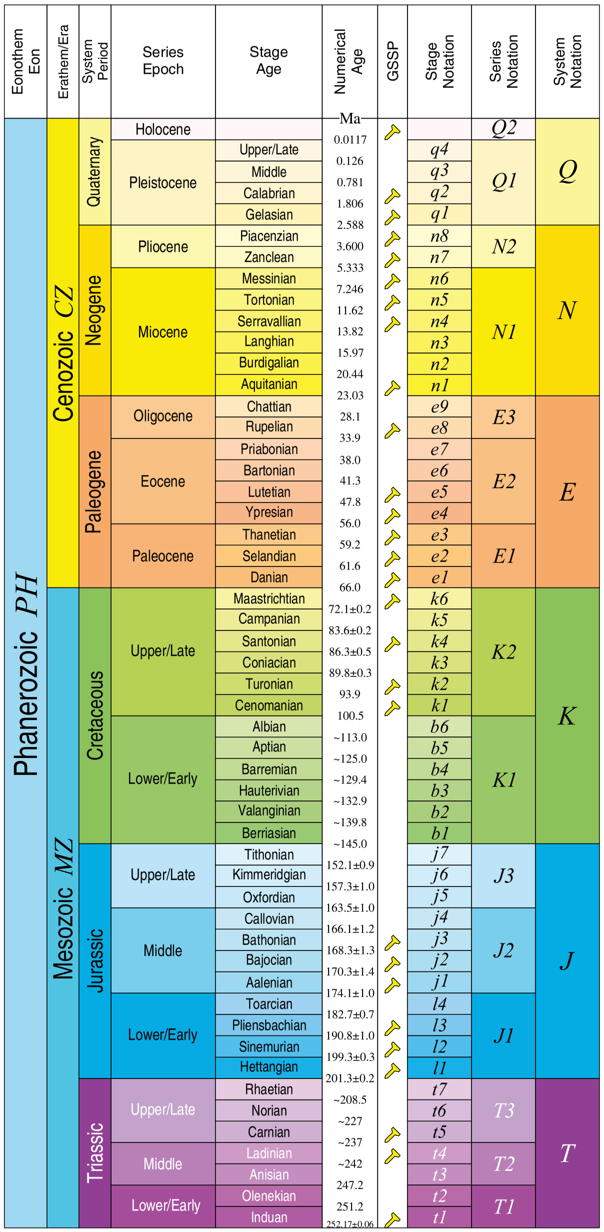
Figure 2. Legend of the Geological Map of Colombia (GMC) 2015, sheet 2. The International Chronostratigraphic Chart (ICC) 2013 was reproduced on the left margin of the sheet. The GMC 2015 working hypothesis (which takes into account that the crustal evolution of Colombia is consequence of successive accretion events) was used to design the gray background of the legend sheet on which chronostratigraphic units (CU) are showed according to their relationship with these tectonic events. 4 CU examples were enlarged with their description of rocks or deposits that compose them. Notice the location maps in the lower left corner of each terrane, whose 3 were expanded as examples. (RNJP) Río Negro–Juruena Province, (CHT) Chibcha Terrane, (TT) Tahamí Terrane, (AT) Anacona Terrane, (QT) Quebradagrande Terrane, (ART) Arquía Terrane, (CT) Caribe Terrane and (LGT) La Guajira Terrane.


Geological Map of Colombia 2015
Sheet 2
LEGEND
ICC
LGT
CT
7. CT
ART
QT
TT
AT
4. AT
100 km
CHT
2. CHT
RNJP
E3-Pi
Granodiorites and tonalites varying to quartz diorites and diorites
Q1-af
Dissected alluvial fans
b5k6-Sm
Limestones, calcareous mudstones, and shales. Also phosphorites, cherts, bentonites, and glauconitic sandstones.
T-Mmg3
Quartzofeldspathic gneisses some with sillimanite, cordierite, and hornblende; amphibolites; migmatites; schists, and marbles.

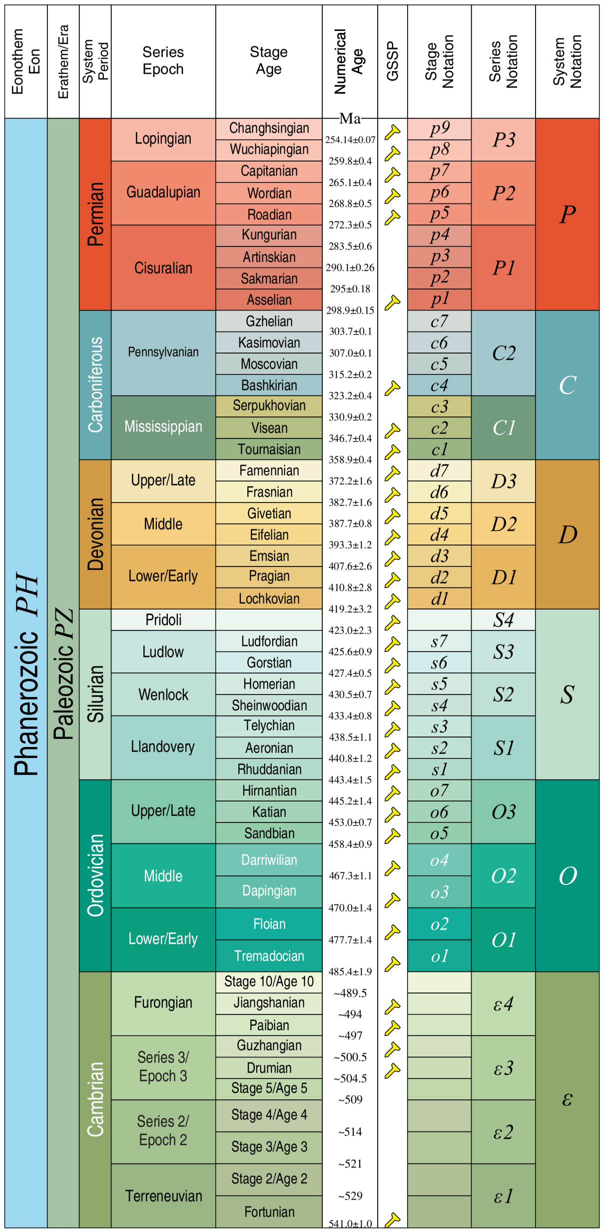
ICS

International Chronostratigraphic Chart 2013
International Commission on Stratigraphy

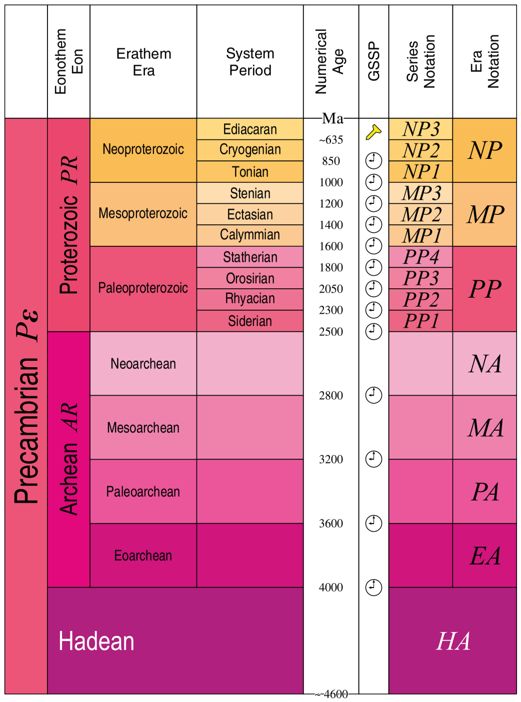
IUGS



Eonothem Eon	Erathem/Era	System Period	Series Epoch	Stage Age	Numerical Age (Ma)	GSSP	Stage Notation	Series Notation	System Notation
Phanerozoic *PH*	Cenozoic *CZ*	Quaternary	Holocene		0.0117	⚑		*Q2*	*Q*
			Pleistocene	Upper/Late	0.126		*q4*	*Q1*	
				Middle	0.781		*q3*		
				Calabrian	1.806	⚑	*q2*		
				Gelasian	2.588	⚑	*q1*		
		Neogene	Pliocene	Piacenzian	3.600	⚑	*n8*	*N2*	*N*
				Zanclean	5.333	⚑	*n7*		
			Miocene	Messinian	7.246	⚑	*n6*	*N1*	
				Tortonian	11.62	⚑	*n5*		
				Serravallian	13.82	⚑	*n4*		
				Langhian	15.97		*n3*		
				Burdigalian	20.44		*n2*		
				Aquitanian	23.03	⚑	*n1*		
		Paleogene	Oligocene	Chattian	28.1		*e9*	*E3*	*E*
				Rupelian	33.9	⚑	*e8*		
			Eocene	Priabonian	38.0		*e7*	*E2*	
				Bartonian	41.3		*e6*		
				Lutetian	47.8	⚑	*e5*		
				Ypresian	56.0	⚑	*e4*		
			Paleocene	Thanetian	59.2	⚑	*e3*	*E1*	
				Selandian	61.6	⚑	*e2*		
				Danian	66.0	⚑	*e1*		
	Mesozoic *MZ*	Cretaceous	Upper/Late	Maastrichtian	72.1±0.2	⚑	*k6*	*K2*	*K*
				Campanian	83.6±0.2		*k5*		
				Santonian	86.3±0.5	⚑	*k4*		
				Coniacian	89.8±0.3		*k3*		
				Turonian	93.9	⚑	*k2*		
				Cenomanian	100.5	⚑	*k1*		
			Lower/Early	Albian	~113.0		*b6*	*K1*	
				Aptian	~125.0		*b5*		
				Barremian	~129.4		*b4*		
				Hauterivian	~132.9		*b3*		
				Valanginian	~139.8		*b2*		
				Berriasian	~145.0		*b1*		
		Jurassic	Upper/Late	Tithonian	152.1±0.9		*j7*	*J3*	*J*
				Kimmeridgian	157.3±1.0		*j6*		
				Oxfordian	163.5±1.0		*j5*		
			Middle	Callovian	166.1±1.2		*j4*	*J2*	
				Bathonian	168.3±1.3	⚑	*j3*		
				Bajocian	170.3±1.4	⚑	*j2*		
				Aalenian	174.1±1.0	⚑	*j1*		
			Lower/Early	Toarcian	182.7±0.7		*l4*	*J1*	
				Pliensbachian	190.8±1.0	⚑	*l3*		
				Sinemurian	199.3±0.3	⚑	*l2*		
				Hettangian	201.3±0.2	⚑	*l1*		
		Triassic	Upper/Late	Rhaetian	~208.5		*t7*	*T3*	*T*
				Norian	~227		*t6*		
				Carnian	~237	⚑	*t5*		
			Middle	Ladinian	~242	⚑	*t4*	*T2*	
				Anisian	247.2		*t3*		
			Lower/Early	Olenekian	251.2		*t2*	*T1*	
				Induan	252.17±0.06	⚑	*t1*		



Eonothem Eon	Erathem/Era	System Period	Series Epoch	Stage Age	Numerical Age (Ma)	GSSP	Stage Notation	Series Notation	System Notation
Phanerozoic *PH*	Paleozoic *PZ*	Permian	Lopingian	Changhsingian	254.14±0.07	⚑	*p9*	*P3*	*P*
				Wuchiapingian	259.8±0.4	⚑	*p8*		
			Guadalupian	Capitanian	265.1±0.4	⚑	*p7*	*P2*	
				Wordian	268.8±0.5	⚑	*p6*		
				Roadian	272.3±0.5	⚑	*p5*		
			Cisuralian	Kungurian	283.5±0.6		*p4*	*P1*	
				Artinskian	290.1±0.26		*p3*		
				Sakmarian	295±0.18		*p2*		
				Asselian	298.9±0.15	⚑	*p1*		
		Carboniferous	Pennsylvanian	Gzhelian	303.7±0.1		*c7*	*C2*	*C*
				Kasimovian	307.0±0.1		*c6*		
				Moscovian	315.2±0.2		*c5*		
				Bashkirian	323.2±0.4	⚑	*c4*		
			Mississippian	Serpukhovian	330.9±0.2		*c3*	*C1*	
				Visean	346.7±0.4	⚑	*c2*		
				Tournaisian	358.9±0.4	⚑	*c1*		
		Devonian	Upper/Late	Famennian	372.2±1.6	⚑	*d7*	*D3*	*D*
				Frasnian	382.7±1.6	⚑	*d6*		
			Middle	Givetian	387.7±0.8	⚑	*d5*	*D2*	
				Eifelian	393.3±1.2	⚑	*d4*		
			Lower/Early	Emsian	407.6±2.6	⚑	*d3*	*D1*	
				Pragian	410.8±2.8	⚑	*d2*		
				Lochkovian	419.2±3.2	⚑	*d1*		
		Silurian	Pridoli		423.0±2.3	⚑		*S4*	*S*
			Ludlow	Ludfordian	425.6±0.9	⚑	*s7*	*S3*	
				Gorstian	427.4±0.5	⚑	*s6*		
			Wenlock	Homerian	430.5±0.7	⚑	*s5*	*S2*	
				Sheinwoodian	433.4±0.8	⚑	*s4*		
			Llandovery	Telychian	438.5±1.1	⚑	*s3*	*S1*	
				Aeronian	440.8±1.2	⚑	*s2*		
				Rhuddanian	443.4±1.5	⚑	*s1*		
		Ordovician	Upper/Late	Hirnantian	445.2±1.4	⚑	*o7*	*O3*	*O*
				Katian	453.0±0.7	⚑	*o6*		
				Sandbian	458.4±0.9	⚑	*o5*		
			Middle	Darriwilian	467.3±1.1	⚑	*o4*	*O2*	
				Dapingian	470.0±1.4	⚑	*o3*		
			Lower/Early	Floian	477.7±1.4	⚑	*o2*	*O1*	
				Tremadocian	485.4±1.9	⚑	*o1*		
		Cambrian	Furongian	Stage 10/Age 10	~489.5			*ε4*	*ε*
				Jiangshanian	~494	⚑			
				Paibian	~497	⚑			
			Series 3/ Epoch 3	Guzhangian	~500.5	⚑		*ε3*	
				Drumian	~504.5	⚑			
				Stage 5/Age 5	~509				
			Series 2/ Epoch 2	Stage 4/Age 4	~514			*ε2*	
				Stage 3/Age 3	~521				
			Terreneuvian	Stage 2/Age 2	~529			*ε1*	
				Fortunian	541.0±1.0	⚑			



	Eonothem Eon	Erathem Era	System Period	Numerical Age (Ma)	GSSP	Series Notation	Era Notation
Precambrian *Pε*	Proterozoic *PR*	Neoproterozoic	Ediacaran	~635	⚑	*NP3*	*NP*
			Cryogenian	850	◷	*NP2*	
			Tonian	1000	◷	*NP1*	
		Mesoproterozoic	Stenian	1200	◷	*MP3*	*MP*
			Ectasian	1400	◷	*MP2*	
			Calymmian	1600	◷	*MP1*	
		Paleoproterozoic	Statherian	1800	◷	*PP4*	*PP*
			Orosirian	2050	◷	*PP3*	
			Rhyacian	2300	◷	*PP2*	
			Siderian	2500	◷	*PP1*	
	Archean *AR*	Neoarchean		2800	◷		*NA*
		Mesoarchean		3200	◷		*MA*
		Paleoarchean		3600	◷		*PA*
		Eoarchean		4000	◷		*EA*
	Hadean			~4600			*HA*

Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP ⚑) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.

Numerical ages for all systems except Permian, Triassic, Cretaceous and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012); those for the Permian, Triassic and Cretaceous were provided by the relevant ICS subcommissions.

Coloring and notations follows the Commission for the Geological Map of the World. http://www.ccgm.org

CCGM CGMW

Chart drafted by K.M. Cohen, S. Finney, P.L. Gibbard

http://www.stratigraphy.org/ICSchart/ChronostratChart2013-01.pdf

Figure 3. International Chronostratigraphic Chart 2013. This version was prepared using the design and notations of the International Stratigraphic Chart from Remane (2000); it follows the colors of the Commission for the Geological Map of the World (Pellé, 2008); and units of all ranks, chronostratigraphic boundaries, Global Boundary Stratotype Section and Points (GSSP), Global Standard Stratigraphic Ages (GSSA), and numerical ages were taken from the International Chronostratigraphic Chart from Cohen *et al.* (2013).

In addition, when an acronym is followed by one digit, this number represents the geological terrane (e. g. *K2–Vm7* refers to Upper Cretaceous mafic volcanic rocks of the Caribbean Terrane). Geological terrane is used here in the sense of Neuendorf *et al.* (2005) as "A faulted–bounded body rock of regional extent, characterized by a geologic history different from that of contiguous terranes or bounding continents. A terrane is generally considered to be a discrete allochthonous fragment of oceanic or continental material added to a craton at an active margin by accretion".

The Geological Terranes Map of Colombia proposal (Figure 5) was performed based on information compiled for the GMC and the "Radiometric dating catalog of Colombia in ArcGIS and Google Earth" (Gómez *et al*., 2015). **In this map, the Anacona Terrane is used *sensu* Martens *et al.* (2014), the Tahamí and Chibcha terranes *sensu* Restrepo *et al.* (2011) and the Río Negro–Juruena province *sensu* Tassinari & Macambira (1999).** This working hypothesis, which takes into account the crustal evolution of Colombia as a consequence of successive accretion events, was used in the design of the gray background for the legend sheet whose the elements contain the descriptions of the CU and were distributed according to their relationship with these tectonic events (Figure 2).

Finally, when at the beginning of the age notation appears the letter ρ (rho), it indicates that the CU can be assigned to any period after that age (e. g. *ρT–Sm* was assigned to marine sedimentary rocks with a post–Triassic age).

Project development

The GMC compilation process was completed in 2007, and in December 2014 ended the edition that is released in 2015. During this time, the working team were composed of geologist of CGS and consisted from three to five participants. Project coordination was managed by the MPhil Álvaro NIVIA GUEVARA between 2002 and 2003. Then the project changed hands to the geologist Jorge GÓMEZ TAPIAS who lead the project from 2004 to present.

For compilation purposes of the digital cartographic information, the country was divided in seven regions. During this stage of the project, all structural information such as faults and folds as well as CU corresponding to these same regions were integrated in independent files. Then they were subsequently edited and synthesized in single integrated files for each of these features. At the end of the compilation stage the CU integrated file contained 471 units that were synthesized up to 169 CU in GMC 2007, and 187 CU in the final GMC 2015. A similar task of synthesizing was carried out for editing the structural elements. In the foothills of the Eastern Cordillera where available information is scarce, an effort was made to improve interpreted structural information of aerial photos and Landsat TM (bands 457) imagery. After release of the GMC in its 2007 edition, the updating process of the GMC has been continuous and for 2015 edition have been integrated 120 new geological maps at a scale of 1:100 000, produced by the SGC from beginning 2006 to December 2013.

It was taken into account the wide area extent and distribution of Cretaceous rocks and their local importance as source hydrocarbons. Thereby, it was decided to carry out a special study focused on better codification definitions. This study consisted of a review of the lithostratigraphic unit ages assigned to each of the geological cartographic data sources and the methods used to date them (Gaona Narváez, 2005). Subsequently, the time intervals that corresponds to the ammonite content reported for each unit were verified. Finally, on this basis, an update of the biostratigraphic correlation between lithostratigraphic units was achieved. Based on this information, 20 CU were separated within the Cretaceous rock sequence. This separation allows to figure out the diachronous nature of these units, the spatial and temporal variation of the sedimentary facies and the subsequential interpretation of the transgressive or regressive movements of the sea during the Cretaceous. This work can be viewed in this volume in "El Cretácico sedimentario al este de la Falla San Jerónimo: Compilación para el Mapa Geológico de Colombia" (Gaona Narváez, 2015).

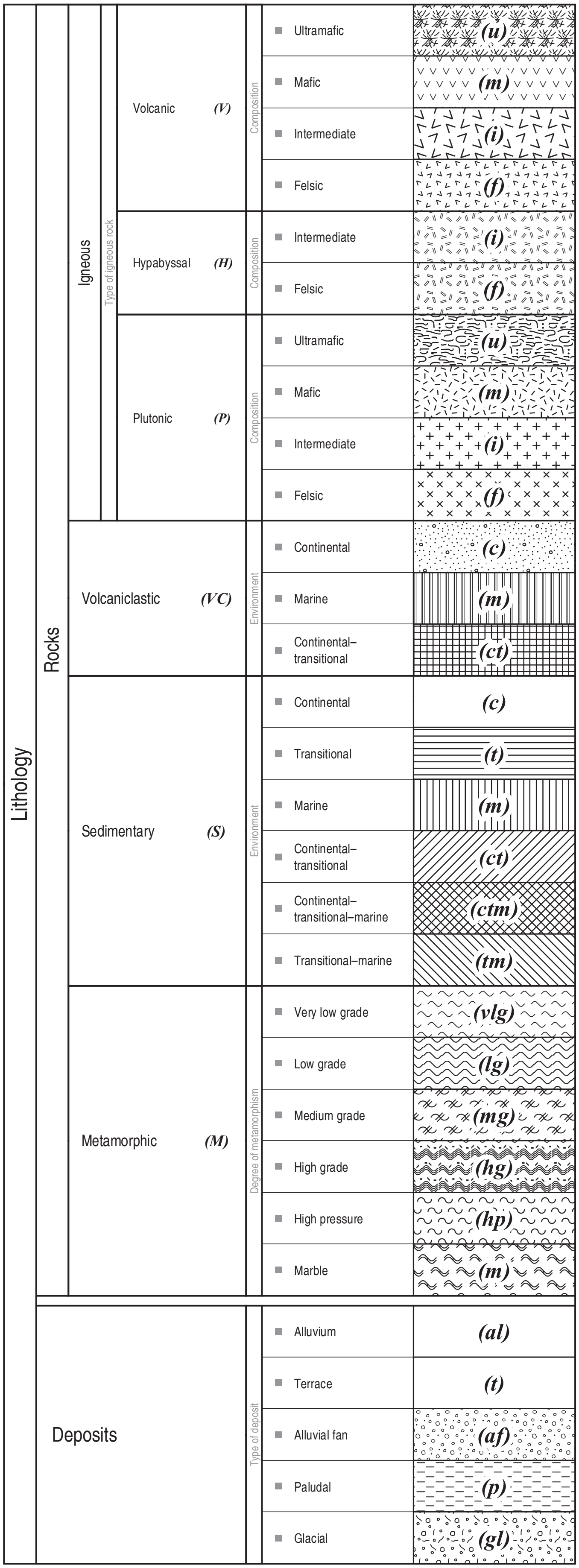
Once all the information was integrated and with the help of draft printed map, the work proceeded on the digital editing that was necessary to convert the innumerable sinuous and zigzagging lines which resulted from reducing the scale 10 times from the original map information into smooth and legible boundaries, always checked by satellite images and shaded relief images.

Taking into account that proper map readings of the colors and patterns used for the representation of CU were insufficient, additional annotations were added containing the map code identification of individual units, as well as the names of the main tectonic structures. These annotations were put on the map to facilitate identification of each polygon in such a way they do not interfere with the annotations of the base map, that were eventually modified.

GIS

As a part of building the structure of the digital database for the GMC a data model was designed. In addition to its characteristics as an independent GIS for an ArcMap–ArcGIS File Geodatabase (geographic database), it was implemented into a corporate geodatabase integrated to the CGS´s GIS. CGS´s GIS is supported by a technological platform that handles data with the database management system Oracle 10g, spatial data engine ArcSDE 9.1 and ArcGIS 9.3.1 for spatial data handling.

For the GAC 2007 was created an extension in the toolbar named SIGER 500 within ArcGIS 9.3.1, developed in VisualBasic.Net that has to be installed and connected with the Oracle Database. This application was the result of a collaborative effort with the system engineer Berenice GALÁN CADENA, the geologist Jorge GÓMEZ TAPIAS and the programmer Guillermo MUÑOZ DUPUY. The functionalities that were developed are shown in Figure 6 and are described below.



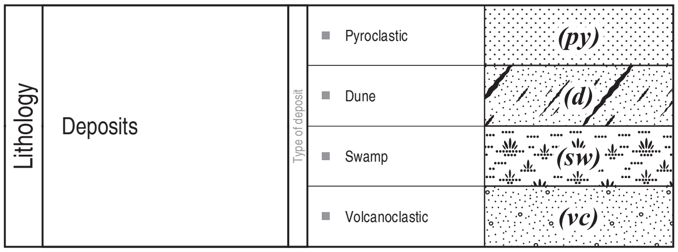


Figure 4. Lithologic pattern chart

The first functionality is the **Security and access**, where everyone requires a user and password. The second one is the **Spatial objects,** that permits to download information from the corporate geodatabase. The third is the **Administration and version management** that allows to administrate and manage different versions of the information contributing to the rules and system security policies and thus to ensure data integrity.

This functionality facilitates the creation of different GAC´s versions. This leaves open the possibility of different geological interpretations or to create different thematic maps such as a hydrologic map or a Quaternary faults map. The forth functionality is the **Display**; this facilitates the display of visualized information either on screen or on paper. These capabilities allow the location or display of a map as a specific sheet and also allow making a map draft with the layers displayed in different paper sizes. The fifth is the **Products generation**, which allows the deployment and printing of products or final maps and exports them. The sixth is the **Metadata**, the seventh is the **Consulting**, the eighth is the **Help** and the ninth is the **Dynamic legend.**

In order to explain the **Dynamic legend** is necessary to indicate that the GAC consists of 26 sheets of 68 × 131 cm of hight at a scale of 1:500 000, following the official map sheet division established by the IGAC for Colombia (Figure 7). The GAC 2015 template has the following insets shown in the Figure 8.

As the GAC 2015 is stored as a single map and database, and not as separate independent sheets, the Dynamic Legend allows to create the map legend in two ways. The first option allows to create the sheets dynamically according to the official grid established by the IGAC. The second one allows users to create a custom map covering a particular area of interest, with the plane coordinates with Mercator projection (UTM projections) required by the user, but with the limitation on the map size of 47 × 68 cm. The insets working dynamically are the map itself, the legend, the CU description, the index sheet map and cartographical sources. At the moment, the extension SIGER 500 is limited to the SGC´s users only.

For external users it is possible to query, the Web version of the GAC 2015 and GMC 2015 through the Web site of the CGS in the following link: http://srvags.sgc.gov.co/Flexviewer/Atlas_Geologico_Colombia_2015/ and http://srvags.sgc.gov.co/Flexviewer/Mapa_Geologico_Colombia_2015/.

(xi) Finally, for users who do not have ArcGIS, the GAC 2015 and GMC 2015 were implemented as image overlays in Google Earth. The CU layer attributes can be displayed clicking on the map because the CU layer is overlaid with 99 % of transparency (Figure 9). Likewise, the Colombian volcanoes are also included as layers in the KMZ files. The GAC 2015 and GMC 2015 in Google Earth can be downloaded from: http://www.sgc.gov.co/images/mapgeo/03_agc2015/KMZ/agc2015_kmz.zip and http://www.sgc.gov.co/images/mapgeo/01_mgc2015/KMZ/mgc2015_kmz.zip.

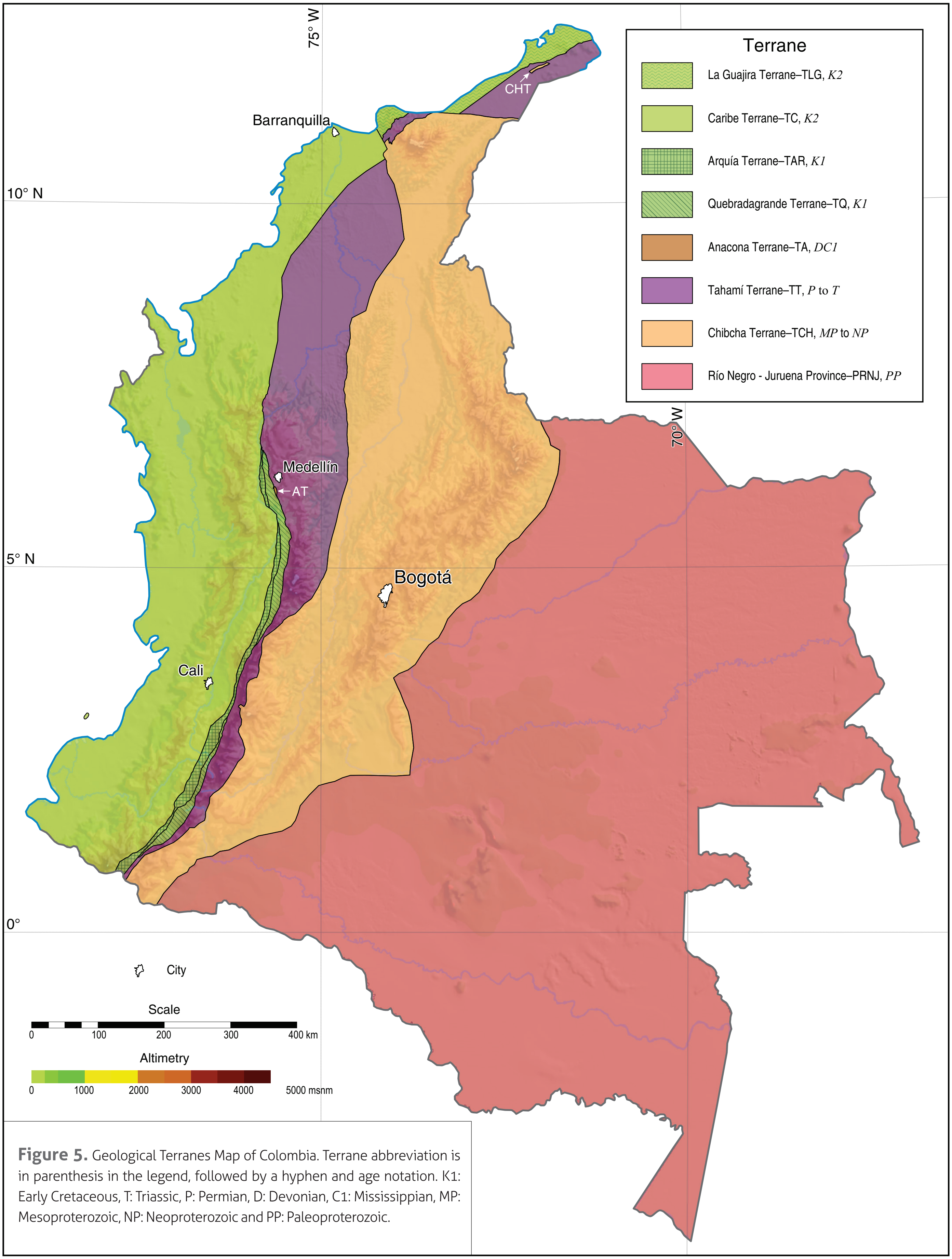


Figure 5. Geological Terranes Map of Colombia. Terrane abbreviation is in parenthesis in the legend, followed by a hyphen and age notation. K1: Early Cretaceous, T: Triassic, P: Permian, D: Devonian, C1: Mississippian, MP: Mesoproterozoic, NP: Neoproterozoic and PP: Paleoproterozoic.

Figure 6. Functionalities of the extension SIGER 500K. (1) Security and access, (2) Spatial objects functionalities, (3) Administration and version management, (4) Display, (5) Template and products generation, (6) Metadata, (7) Searching, (8) Help and (9) Dynamic legend.

Future revisions and updates

The new GMC 2015 was released on 20th August 2015, 99 years after anniversary of the foundation of the Colombian National Scientific Commission ordered by the Law 83 of 1916 with the task of surveying Colombian territory. This map summarizes the work of exploration and geological investigations carried out since then. However, never before the information has been as accessible as now, when it is available on a GIS. Nowadays, we have a system that not only permits easy consultation but also facilitates rapid updating. We follow the words of Reed *et al.* (2005b), who in reference to future revisions and additions to the Geological Map of North America (Reed *et al.* 2005a) emphasizes that any geological map has to be considered as a work in progress subject to continuous updating, revision and addition. As such, the GMC is not a static document but is one that is open to continuous modification and improvement in the light of new information and scientific advances in the interpretation of geological phenomena. **The periodic production of this document is one the main function of the Colombian Geological Survey**, according to Decree 4131 of November 3rd, 2011 of the Ministry of Mines and Energy.

Final considerations

- The GMC 2015 (SIG, PDF and TIFF), the 26 sheets of the GAC 2015 (SIG, PDF, TIFF and KMZ) and the Radiometric Dating Catalog of Colombia (SIG, KMZ and reference manager database in ENL) can be downloaded for free in the following URL:http://www.sgc.gov.co/Geologia/Mapa-geologico-de-Colombia.aspx.
- The GMC has structured all its GIS and annotations in English.
- The CU named *NP3–Sm* in the GMC has not been differentiated in geological mapping of the CGS but it was included in Sheet 2–Legend of the GMC. This unit includes sedimentary rocks that according to Cáceres *et al.* (2003) contain algal tissue and sphaeromorph acritarchs from Ediacaran, found at the Chigüiro 1 and Patos 1 oil wells in the Arauca Department.

- Citation of the Geological Map of Colombia 2007 at a scale of 1 000 000 is suggested as:

Gómez, J., Nivia, Á., Montes, N.E., Tejada, M.L., Jiménez, D.M., Sepúlveda, M.J., Osorio, J.A., Gaona, T., Diederix, H., Uribe, H. & Mora, M., compilers, 2007. Geological Map of Colombia 2007. Scale 1:1 000 000. INGEOMINAS, 2 sheets. Bogotá.

- Citation of the Geological Atlas of Colombia 2007 at a scale of 500 000 is suggested as:

Gómez, J., Nivia, Á., Montes, N.E., Jiménez, D.M., Sepúlveda, J., Gaona, T., Osorio, J.A., Diederix, H., Mora, M. & Velásquez, M.E., compilers. 2007. Atlas Geológico de Colombia. Scale 1:500 000. INGEOMINAS, 26 sheets. Bogotá.

- Citation of the Geological Map of Colombia 2015 at a scale of 1 000 000 is suggested as:

Gómez, J., Montes, N.E., Nivia, Á. & Diederix, H., compilers. 2015. Geological Map of Colombia 2015. Scale 1:1 000 000. Colombian Geological Survey, 2 sheets. Bogotá.

- Citation of the Geological Atlas of Colombia 2015 at a scale of 500 000 is suggested as:

Gómez, J., Montes, N.E., Nivia, Á. & Diederix, H., compilers. 2015. Atlas Geológico de Colombia 2015. Scale 1:500 000. Colombian Geological Survey, 26 sheets. Bogotá.

- Any suggestion intending to improve the Geological Map of Colombia, please contact geologist Jorge GÓMEZ TAPIAS–Coordinator of the Geological Map of Colombia Project at the E–mail: mapageo@sgc.gov.co.

References

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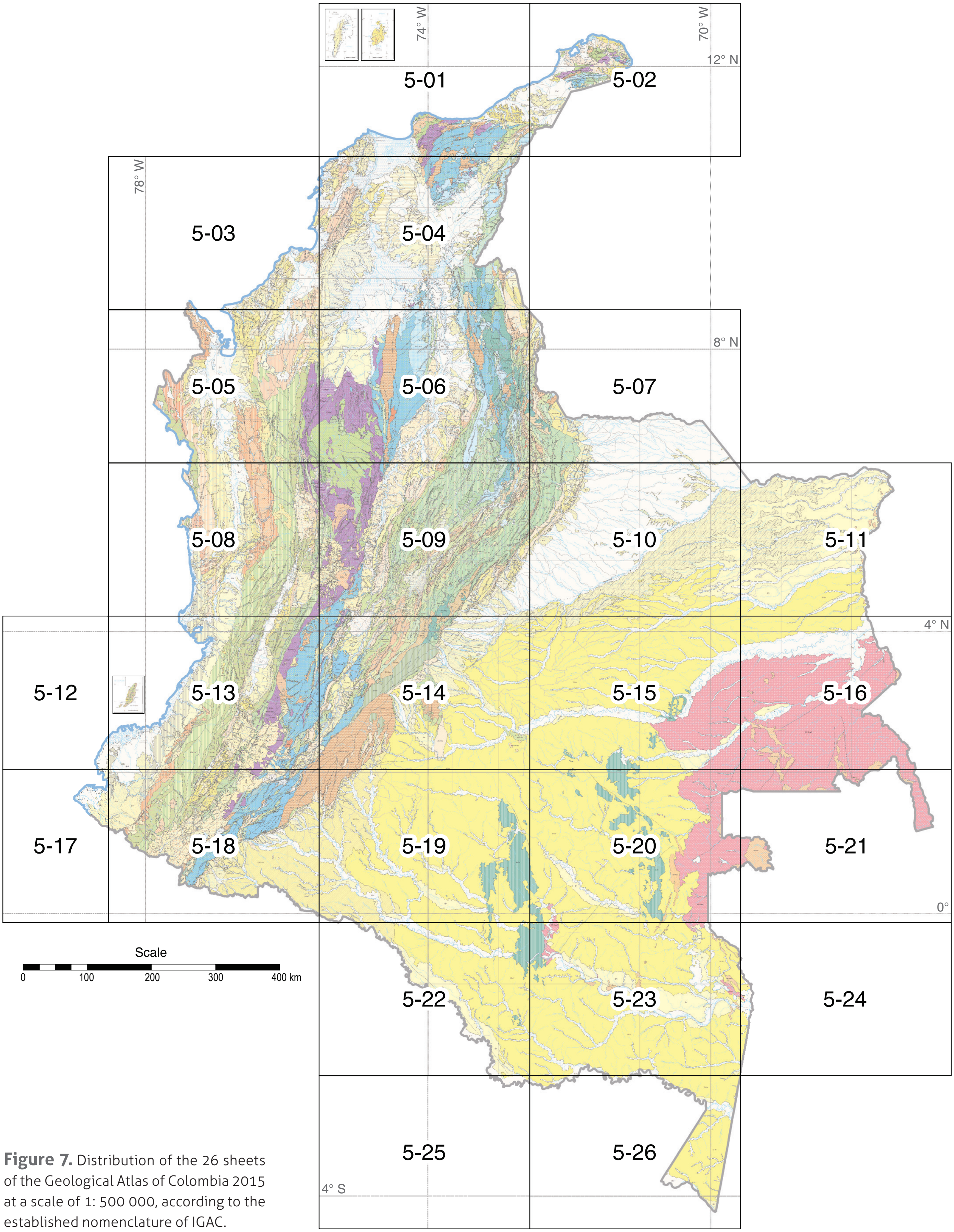


Figure 7. Distribution of the 26 sheets of the Geological Atlas of Colombia 2015 at a scale of 1: 500 000, according to the established nomenclature of IGAC.

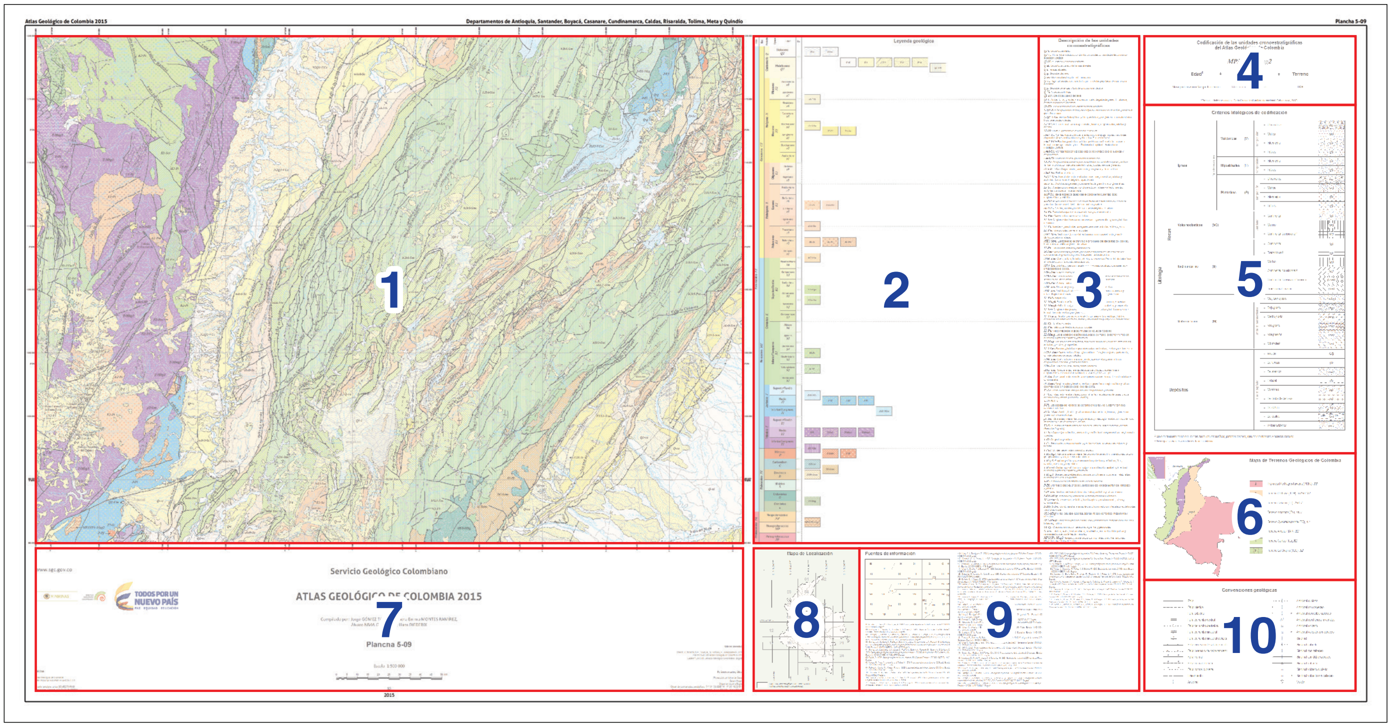
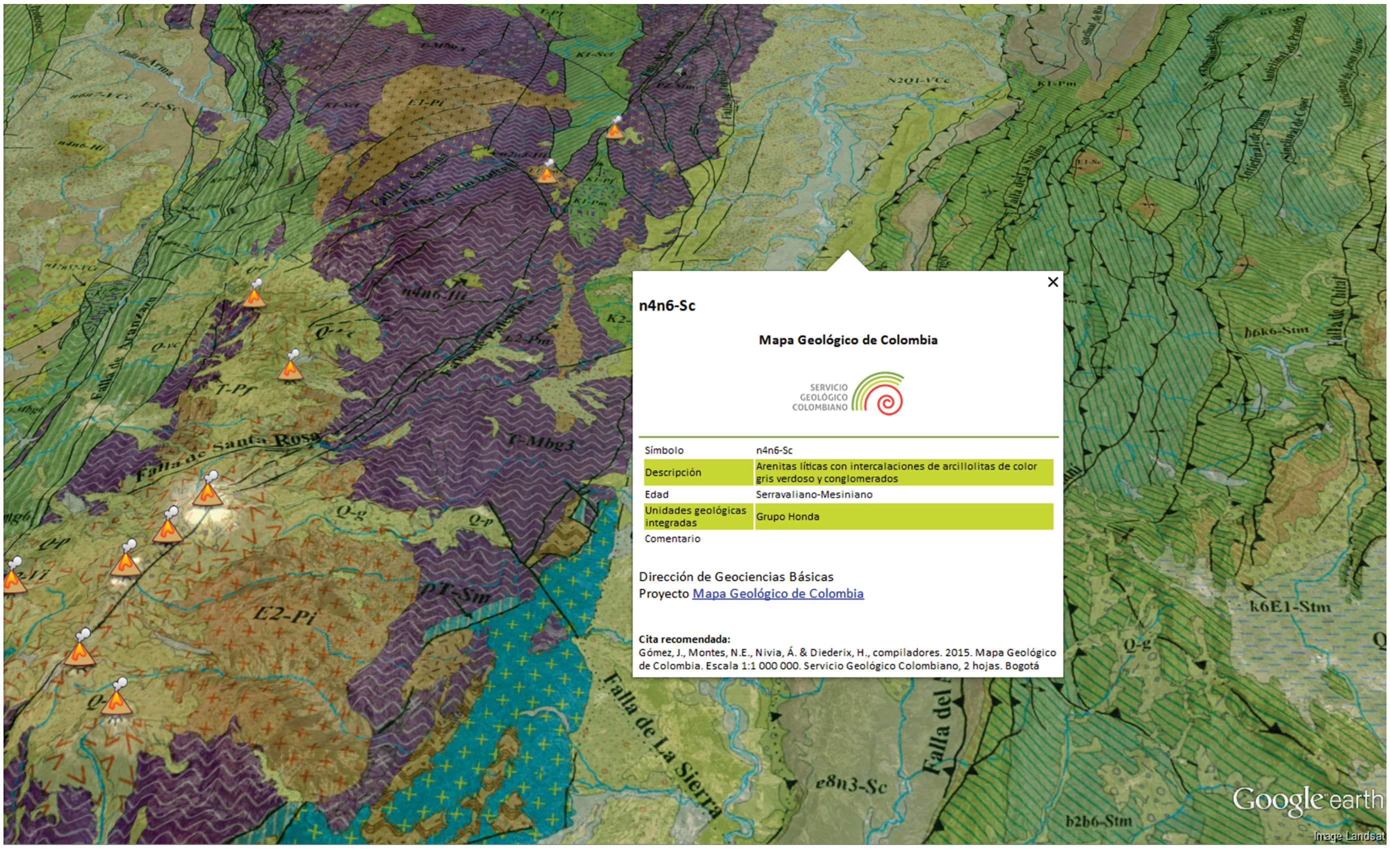


Figure 8. Geological Atlas of Colombia 2015 insets. (1) Geological Atlas of Colombia, (2) geological legend, (3) chronostratigraphic units description, (4) codification of chronostratigraphic units, (5) lithologic pattern chart, (6) Geological Terranes Map of Colombia, (7) credits, (8) index sheet, (9) cartographic sources, and (10) geological conventions.



n4n6-Sc

Mapa Geológico de Colombia

SERVICIO GEOLÓGICO COLOMBIANO

Símbolo	n4n6-Sc
Descripción	Arenitas líticas con intercalaciones de arcillolitas de color gris verdoso y conglomerados
Edad	Serravaliano-Mesiniano
Unidades geológicas integradas	Grupo Honda
Comentario	

Dirección de Geociencias Básicas
Proyecto Mapa Geológico de Colombia

Cita recomendada:
Gómez, J., Montes, N.E., Nivia, Á. & Diederix, H., compiladores. 2015. Mapa Geológico de Colombia. Escala 1:1 000 000. Servicio Geológico Colombiano, 2 hojas. Bogotá

Figure 9. Geological Map of Colombia 2015 in Google Earth. Note the attributes of chronostratigraphic units displayed. To the left of the figure, volcanoes can be seen with a special symbol that helps to locate them quickly.

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Jorge GÓMEZ TAPIAS is the coordinator of the Geological Map of Colombia Project at Colombian Geological Survey. He is the first author of the Geological Map of Colombia at a scale of 1:1 M and the Geological Atlas of Colombia at a scale of 1:500 K, editions 2007 and 2015. He was appointed since 2010 Secretary General for South America of the Commission for the Geological Map of the World (CGMW) and currently is the co–coordinator for the Geological Map of South America at a scale of 1:5 M and the Geological and Mineral Resources Map of South America at a scale of 1:1 M. He has an extensive experience in Colombian geology, geological mapping, cartographic standards and GIS.

Álvaro NIVIA GUEVARA is a senior geologist at the Colombian Geological Survey in Cali. His research activities are concerned with the geodynamic evolution of western Colombia as a result of the accretion of an Upper Cretaceous oceanic plateau to the continental margin and its consequences on both, the latter and the accreted terranes (e. g. generation of an accretionary prism and the resulting deformation and low grade metamorphism). Nowadays, his interest is the understanding of the origin and emplacement mechanisms of the Upper Cretaceous granitoid belt associated to the accretionary margin.

Nohora Emma MONTES RAMÍREZ is Geologist and hold a postgraduate degree in Geomatic. Works at the Colombian Geological Survey since 1997, where she has worked in different areas such as neotectonic, geological mapping and regional geology, it is remarkable her works in the paleoseismology of the Ibagué Fault. Since 2005, joined the Geological Map of Colombia Project and so is the co–author of the 2007 and 2015 versions of the Geological Map of Colombia and the Geological Atlas of Colombia. In addition, is co–author of the Geological Map of South America at a scale of 1:5 M and the Geological and Mineral Resources Map of South America at a scale of 1:1 M (in preparation), projects of the Commission for the Geological Map of the World (CGMW).

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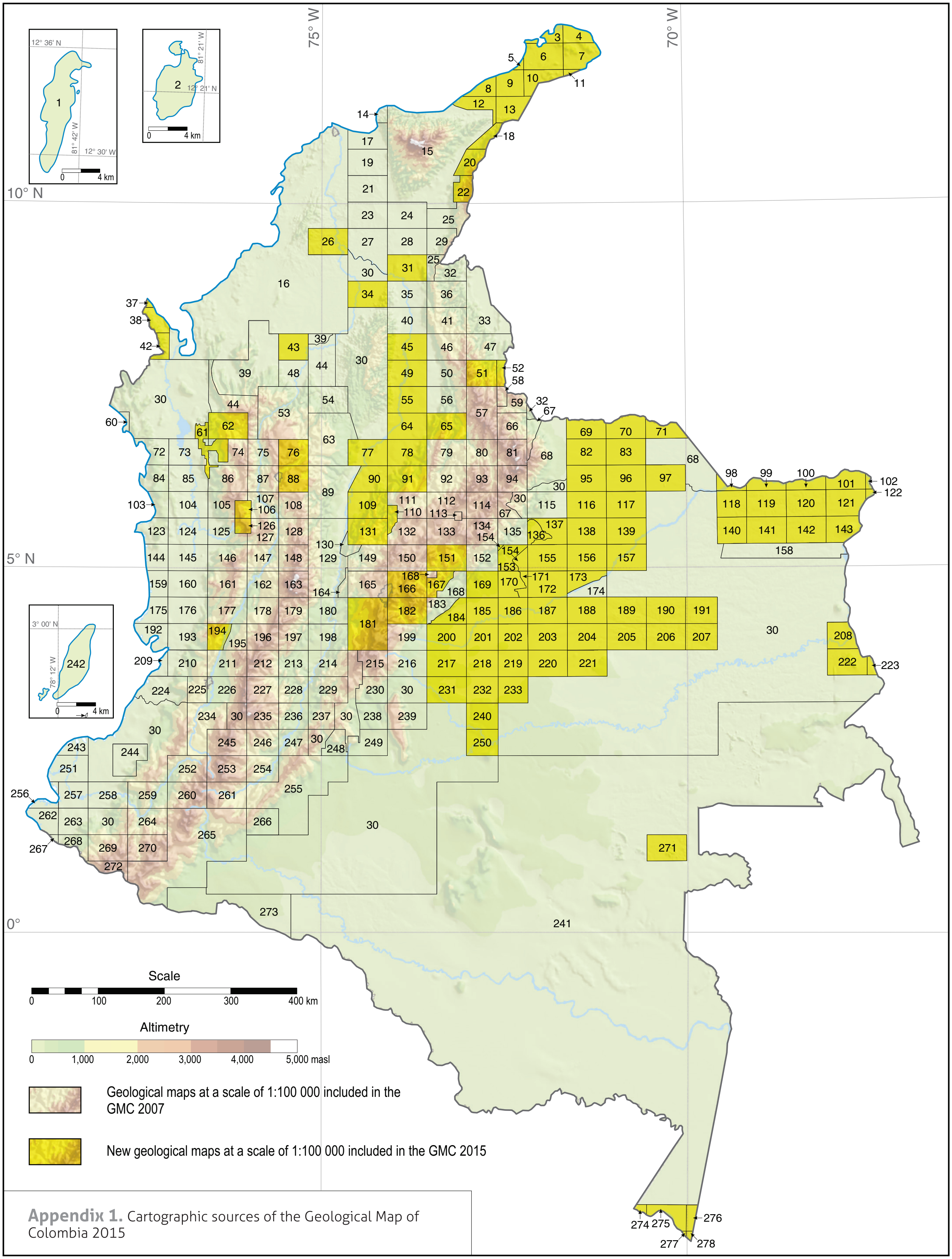
María Fernanda ALMANZA MELÉNDEZ works at the Geological Map of Colombia Project since 2013, where most of her work is concerned with texts edition, English–Spanish translations and is co–author of the book Manual de publicaciones del SGC. She is Geologist and Master in Geology candidate with the Honor Degree scholarship at the National University of Colombia–Bogotá, where she was Editorial Assistant of the Geología Colombiana Journal in 2012. Her main interests are research in petrology and Earth Sciences publications.

Fernando Alirio ALCÁRCEL GUTIÉRREZ is geologist linked to the Geological Map of Colombia Project since 2012, in which supports research works. He developed and implemented the Google Earth version of the “Radiometric Catalog of Colombia in ArcGIS and Google Earth” and the Geological Map of Colombia 2015. He has experience in geological mapping and has GIS skills.

César Augusto MADRID MONTOYA is Geologist, he worked at the Geological Map of Colombia Project from 2008 to 2009, where he worked on the Geological Map of Colombia actualization. Afterwards, he has been made some geological mapping projects such as the compilation of the Geological Map of Perú at a scale of 1:100 000 for Ecopetrol and geological mapping and hydrothermal alterations maps for cupper exploration in the Western Cordillera. Since 2014, works for the Geological Map of Colombia Project again and currently is developing the Geological Map of La Linea Tunnel in the Central Cordillera.



Appendix 1. Cartographic sources of the Geological Map of Colombia 2015

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