

# CURRENT STATE OF EARTH SCIENCES IN COLOMBIA (SOUTH AMERICA)

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## ABSTRACT

Gathered between 1970 and 2010 data on the Colombian System of Science, Technology and Innovation, administrated by COLCIENCIAS<sup>3</sup>, have been analyzed in order to identify development scenarios in the field of Earth Sciences, with particular reference to academic and scientific standards, conformation and tendencies of existing research groups, active research lines, and some characteristics of the education sector, the job market and performance, in the field of Earth Sciences in Colombia.

One of the most relevant results is the identification of a constant strengthening of Earth Sciences field owing to the growing of the number of institutions dedicated to the creation of research groups, the rise of academic publishing, and the impact on the productive reality of Colombia.

Nevertheless, the current state of Earth Sciences in Colombia allows identifying a substantial delay. It must be resolved by institutional reinforcement of involved parts through the integration of cooperative networks, and the planning of a strategic agenda for the next years, based on the practice of technological surveillance and the strengths consolidation.

**Keywords:** Colombia, Earth Sciences, research, development, COLCIENCIAS.

## INTRODUCTION

The analysis of the Earth Sciences status in Colombia requires, at least, the principal antecedents in this field, in order to set up a comparative frame of reference, which gives us an idea of the progress, which has been achieved in the last years, and of the future projections that can possibly be made.

First of all, the results of the “Science and Technology Mission” were examined. Created by decree number 1600 in 1988, this Mission was carried out between 1989 and 1990 giving conclusions regarding conditions of the national scientific development, fields of research, the impact, possibilities of specific training in Colombia, and possible breakthroughs in the 1990’s. The results of this work were published in the mid-1990’s (Briceño and Mojica, 1993). The most significant dates related to Earth Sciences development, which were presented in that study, are:

- **1916** Started an “organized” geological research of Colombian territory owns to the creation of the “National Scientific Commission”.
- **1935** Foundation of the Geographic Institute Agustin Codazzi (IGAC<sup>4</sup>), the first entity of Basic Geophysical Research.

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<sup>4</sup> IGAC – Instituto Geográfico Agustín Codazzi (Geographic Institute Agustin Codazzi). www.igac.gov.co

- **1938** The “National Scientific Commission” cleared the way to the “National Geological Service”, which in 1940 became part of the Ministry of Mines and Petroleum, founded in the same year. It consisted in several departments, such as Stratigraphy, Paleontology, Geology, Economics, Library and Museum. This structure was conserved, with some modifications, until 1963.
- **1941** The Geophysical Institute of the Colombian Andes<sup>5</sup> was founded.
- **1942** Based on the School of Mines of Medellin (created in 1887), the “Geology and Petroleum” program, in the Faculty of Mines of the National University of Colombia<sup>6</sup> (founded in 1940), was launched.
- **1951** Creation of the Colombian Petroleum Company (ECOPETROL<sup>7</sup>) entrusted to boost and supervise exploitation, extraction and refining of hydrocarbons.
- **1956** Foundation of the Geological Department at the National University of Colombia<sup>8</sup> (Bogota campus).
- **1963** The National Government undertook, with the aid of the United States Geological Survey, the Mining Inventory that existed till 1968 as a parallel entity to the National Geological Service.
- **1968** Through the fusion of the Geological Service, the Mining Inventory and the National Chemical Laboratory (founded in 1928), the Colombian Government created the National Institute of Geological and Mining Researches (INGEOMINAS<sup>9</sup>).
- **1974-1982** As a result of the “energy crisis”, many petroleum and mine companies, interested mostly in extraction of uranium, came to Colombian market. According to several studies carried out at that time, in the 1980’s geologists (and geophysicists) were in greater demand, which led to following conclusions: it was important at that moment to a) Strengthen the current academic programs; b) Introduce new geology and/or geophysics programs; c) Create private institutes of Earth Sciences.
- **Starting in the 1980’s** the Geology program was launched at the following universities: Industrial University of Santander (UIS<sup>10</sup>) (Bucaramanga city), University of Caldas<sup>11</sup> (Manizales city), and University of Administrative Studies, Finances and Technologies (EAFIT<sup>12</sup>) (Medellin city), and the program of Geological Engineering at the Technical Pedagogical University of Colombia (UPTC<sup>13</sup>) (Sogamoso city), and at the Engineering School of Antioquia (EIA)<sup>14</sup> (Medellin city).
- **1985** The National University of Colombia (Bogota campus), in collaboration with an international program for the development of the research capacity (ICFES<sup>15</sup>-IADB<sup>16</sup>), launches the Master in Geophysics program.
- **1987** The Southwest Seismological Observatory is founded.
- **1994** Inauguration of the National Seismological Network of Colombia (RSNC<sup>17</sup>).
- **2003** The National Hydrocarbons Agency (ANH<sup>18</sup>) was created.

<sup>5</sup> Nowadays: Instituto Geofísico Universidad Javeriana (Institute of Geophysics Javeriana University). [fing.javeriana.edu.co/geofisico/](http://fing.javeriana.edu.co/geofisico/)

<sup>6</sup> [www.minas.medellin.unal.edu.co/index.php/es/](http://www.minas.medellin.unal.edu.co/index.php/es/)

<sup>7</sup> ECOPETROL – Empresa Colombiana de Petróleos (Colombian Petroleum Company). [www.ecopetrol.com.co](http://www.ecopetrol.com.co)

<sup>8</sup> [www.geociencias.unal.edu.co/](http://www.geociencias.unal.edu.co/)

<sup>9</sup> Nowadays INGEOMINAS changed its name to Colombian Geological Service. [www.ingeominas.gov.co](http://www.ingeominas.gov.co)

<sup>10</sup> UIS – Universidad Industrial de Santander (Industrial University of Santander). [www.uis.edu.co](http://www.uis.edu.co)

<sup>11</sup> [www.ucaldas.edu.co](http://www.ucaldas.edu.co)

<sup>12</sup> EAFIT – Universidad Escuela de Administración, Finanzas y Tecnologías (University of Administrative Studies, Finances and Technologies).

<sup>13</sup> UPTC – Universidad Pedagógica y Tecnológica de Colombia (Technical Pedagogical University of Colombia). [www.uptc.edu.co](http://www.uptc.edu.co)

<sup>14</sup> EIA – Escuela de Ingeniería de Antioquia (Engineering School of Antioquia). [www.eia.edu.co](http://www.eia.edu.co)

<sup>15</sup> ICFES – Instituto Colombiano para el Fomento de la Educación Superior (Colombian Institute for the Foment of the High Education). [www.icfes.gov.co](http://www.icfes.gov.co)

<sup>16</sup> IADB – Inter-American Development Bank. [www.iadb.org](http://www.iadb.org)

<sup>17</sup> RSNC – Red Sismológica Nacional de Colombia (National Seismological Network of Colombia). [seisan.ingeominas.gov.co/RSNC/](http://seisan.ingeominas.gov.co/RSNC/)

<sup>18</sup> ANH – Agencia Nacional de Hidrocarburos (National Hydrocarbons Agency). [www.anh.gov.co](http://www.anh.gov.co)

The research performed by Espinosa et al. for COLCIENCIAS (Espinosa et al. 1998) analyzes the academic programs offered in Colombia and the role of employers and institutions, such as ICFES and COLCIENCIAS, which promote the education and research. One of the most important conclusions of this work is proving the need of the reconstruction of the Committee of Earth Sciences, which functioned between 1987 and 1990, and to transform it in the future into the National Council of Earth Sciences.

It is also pointed that the level of the academic programs and research is quite poor comparing to any other field of Basic Sciences. This situation can be explained by lack of an efficient national policy regarding education and research in the field of Earth Sciences.

After these outlines, we would like to state some conclusions about a breakthrough that Earth Sciences have had in the last 40 years in Colombia, in order to identify a favorable scenario for their evolution in the region.

### RESEARCH LINES ACTIVE IN 1993

Based on researches, diploma thesis and published works, Briceño and Mojica (1993) stated that in Colombia, in 1993, the principle lines of research in Geology were:

1) Evaluation and exploration of hydrocarbon prospective basins.

Institutions: ECOPETROL-ICP<sup>19</sup>, and companies from the same field.

2) Geology applied to mining.

Institutions: INGEOMINAS, MINERALCO, CARBOCOL, etc.

3) Mineralogy and Petrology.

Institutions: National University of Colombia<sup>20</sup> (Bogota and Medellin campuses), Industrial University of Santander (UIS), University of Caldas, INGEOMINAS, EAFIT.

4) Stratigraphy and Micropaleontology.

Institutions: INGEOMINAS, National University of Colombia (Bogota and Medellin campuses), University of Caldas.

5) Tectonics.

Institutions: National University of Colombia (Bogota and Medellin campuses), INGEOMINAS, Industrial University of Santander (UIS), University of Caldas.

6) Oceanography.

Institutions: CIOH<sup>21</sup>, INGEOMINAS, National University of Colombia (Bogota campus).

7) Volcanic Processes.

Institutions: INGEOMINAS, University of Caldas, National University of Colombia (Bogota and Medellin campuses), EAFIT.

8) Radiometric dating.

Methods: Fission tracks, K/Ar, Rb/Sr and carbon 14.

Institutions: INGEOMINAS, National University of Colombia (Bogota and Medellin campuses).

9) Geothermics.

Institutions: ICEL<sup>22</sup>, National University of Colombia (Bogota), CHEC<sup>23</sup>, INGEOMINAS.

10) Micropaleontology. Including projects on foraminifera and palynology.

Institutions: National University of Colombia (Bogota), Institute of Natural Sciences<sup>24</sup>, ICP-ECOPETROL, INGEOMINAS.

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<sup>19</sup> ICP – Instituto Colombiano del Petróleo (Colombian Institute of Petroleum).

[www.ecopetrol.com.co/especiales/Portafolio%20ICP/portafolio/centro/index.htm](http://www.ecopetrol.com.co/especiales/Portafolio%20ICP/portafolio/centro/index.htm)

<sup>20</sup> [www.unal.edu.co](http://www.unal.edu.co)

<sup>21</sup> CIOH – Centro de Investigaciones Oceanográficas e Hidrográficas (Oceanographic and Hydrographic Research Center). [www.cioh.org.co](http://www.cioh.org.co)

<sup>22</sup> ICEL – Instituto Colombiano de Energía Eléctrica (Colombian Institute of Electrical Energy).

<sup>23</sup> CHEC – Central Hidroeléctrica de Caldas (Hydroelectric Central of Caldas).

<sup>24</sup> [www.icn.unal.edu.co](http://www.icn.unal.edu.co)

11) Environmental Geology.

Institutions: INGEOMINAS, EAFIT, National University of Colombia, University of Caldas, Industrial University of Santander (UIS), Geographic Institute Agustin Codazzi IGAC-CIAF<sup>25</sup>.

12) Cartography, basic and applied Geology.

Institutions: INGEOMINAS, universities, private companies.

13) Hydrogeology.

Institutions: INGEOMINAS, CVC<sup>26</sup>, CAR<sup>27</sup>, National University of Colombia (Bogota and Medellin campuses), private consultants.

14) Remote sensors applied to Geology.

Methods: Conventional aerial color photography, radar and satellite images (MSS/SPOT and Landsat).

Institutions: Geographic Institute Agustin Codazzi IGAC-CIAF, INGEOMINAS, private consultants and EAFIT.

Regarding Geophysics Briceño and Mojica (1993) identify the following:

1) Seismotectonics.

Institutions: thesis works and dissertations presented in Bogota (National University of Colombia) and overseas (USA, USSR, France), international cooperation projects as “Proyecto Nariño”, and the project carried out by the University of Valle and the Swiss government, in order to establish the Southwest Seismological Observatory, as well as the study conducted by French institutions and INGEOMINAS regarding the Bucaramanga seismic nest. The stand out participation of some national entities, such as National Planning Department<sup>28</sup>, regional corporations that conducted studies on seismic and volcanic hazards, and Volcanological Observatories in Colombia was very helpful.

2) Geophysical prospecting.

Institutions: ICP-ECOPETROL, and acquisition, processing and interpretation of seismic data national companies.

3) Geothermics.

Institutions: studies carried out since 1978 mostly by ICEL y la CHEC, in collaboration with Italian government, and OLADE<sup>29</sup>, Ministry of Mines and Energy-COLCIENCIAS.

Briceño and Mojica (1993) also state that the geophysical methods are fundamental for the exploration of subterranean waters as well as for the solution of problems presented in Engineering, in Environmental Geology, and in Prospecting Mining.

Espinosa et al. (1998) identify as a milestone of development the environmental topics related to the Territory Studies, Environmental Management, and the Urban Reform. They emphasize the importance of the Meteorology and works performed by the IDEAM<sup>30</sup> and INGEOMINAS oriented to the promulgation of policies, which are identified in:

1) Earthquake-Resistant Construction Code (1984, 1998).

2) National Prevention System and Disaster-Response Agency (1989).

3) Urban Reform (1989).

4) Environment (1993).

5) Territorial legislation (1997).

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<sup>25</sup> CIAF – Centro de Investigación y Desarrollo en Información Geográfica (Research and Development Center for Geographic Information). [www.igac.gov.co](http://www.igac.gov.co)

<sup>26</sup> CVC – Corporación Autónoma Regional del Valle del Cauca (Autonomous Regional Corporation of Valle del Cauca). [www.cvc.gov.co](http://www.cvc.gov.co)

<sup>27</sup> CAR – Corporación Autónoma Regional de Cundinamarca (Autonomous Regional Corporation of Cundinamarca). [www.car.gov.co](http://www.car.gov.co)

<sup>28</sup> DNP – Departamento Nacional de Planeación (National Planning Department). [www.dnp.gov.co](http://www.dnp.gov.co)

<sup>29</sup> OLADE – Organización Latinoamericana de Energía (Latin American Organization of Energy). [www.olade.org](http://www.olade.org)

<sup>30</sup> IDEAM – Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia (Institute of Hydrology, Meteorology and Environmental Studies of Colombia). [www.ideam.gov.co](http://www.ideam.gov.co)

## EARTH SCIENCES RESEARCH GROUPS ACTIVE IN 2010

Below an analysis of the information registered on the International Network of Information and Knowledge Sources for Science, Technology and Innovation Management (ScienTI Platform<sup>31</sup> administrated in Colombia by COLCIENCIAS) is presented, regarding the research groups emphasized on Earth Sciences.

### Registered and classified groups

The whole list of Colombian groups on the ScienTI Platform by fields of interest was analyzed. There were found 74 registered groups, which declare “Geosciences” as their *Field of Knowledge*. According to COLCIENCIAS, these 74 research groups correspond to the 11% of the registered groups from the “Exact and Earth Sciences” *Global Field of Knowledge* (according to the COLCIENCIAS classification).

The products of these 74 groups, *in general*, are related to Earth Sciences, i.e. involve topics related to the study of the atmosphere, hydrosphere, as well as the solid Earth; however, some of those products are closer to topics like oil and gas industry, ecosystems and environmental management, alternative energies, soil analysis, town planning, waste management, transport engineering, environmental sustainability, ecology, territorial development, etc. whilst, in this study we would like to analyze the contributions of groups that are working in basic research associated with geophysics. Because of that from 74 groups we select only 56, which are directly involved in basic research, for further analysis.

The distribution of groups according to theirs National Programs of Science and Technology (according to COLCIENCIAS classification) is presented in Table 1.

### Classification of groups according to their category

COLCIENCIAS classify the registered research groups according to their relevance (including production, track record, members, etc.) in five categories: A1, A, B, C and D, where category A1 is the higher one. The groups without a defined category are considered like “acknowledged”. The number of groups according to their categories is shown on Figure 1.

Table 1. Distribution of 56 Research Groups, which declare “Geosciences” as their *Field of Knowledge*, according to theirs National Programs of Science and Technology. The research lines corresponding to each Program, and which are under consideration in the present analysis, are enclosed in parentheses

National Program of Science and Technology (research lines)	Number of Groups
Basic Sciences (Earth sciences)	27
Electronics, Telecommunications and Informatics (complex and intelligent systems, geographic and environmental informatics systems)	1
Energy and Mining Research (exploration and exploitation technologies of mining and energy resources)	6
Environment, Biodiversity and Habitat (risk management and global climate change)	19
Sea and Hydrobiological Resources (climatology and meteorology, global change, oceanography and hydrography, marine geology and geomorphology, minerals and hydrocarbons, alternative energies)	3
<b>TOTAL</b>	<b>56</b>

<sup>31</sup> ScienTI Platform. [www.colciencias.gov.co/scienti](http://www.colciencias.gov.co/scienti)

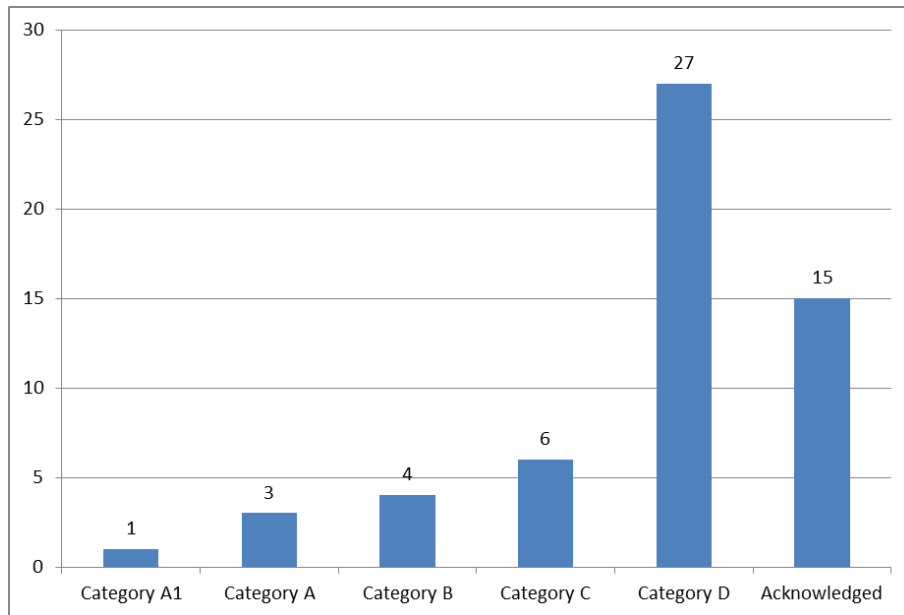


Figure 1. Number of groups according to their category.

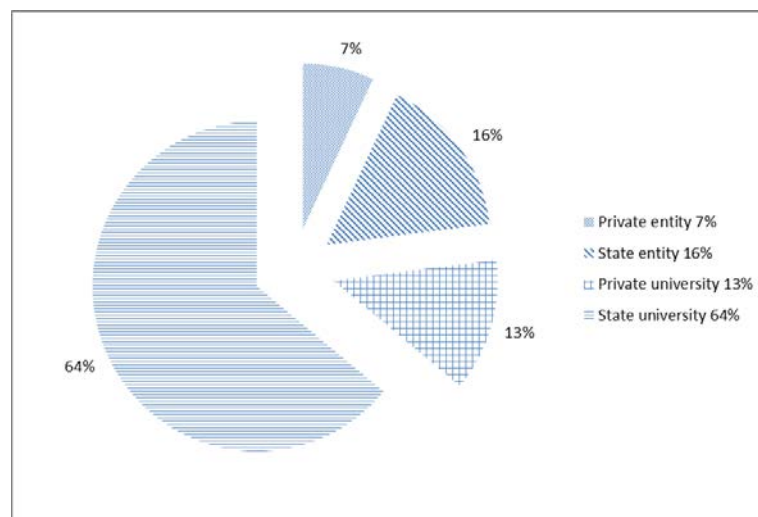


Figure 2. Classification of groups based on the type of institution they belong to.

***Classification of groups based on the type of institution they belong to***

Of 56 groups registered in ScienTI Platform, 7% correspond to private entities, 16% to state entities, 13% to private universities, and 64% to public universities (Figure 2).

***Classification of groups based on the year of creation***

The first research groups in the field of Earth Sciences were created in 70's and 80's, but only in the late 90's the number of groups started increasing (Figure 3). This increase can be related to the decrease of the energy and mining "boom". As a consequence, universities and institutions provided with more sophisticated technical equipment look at new problems more systematically.

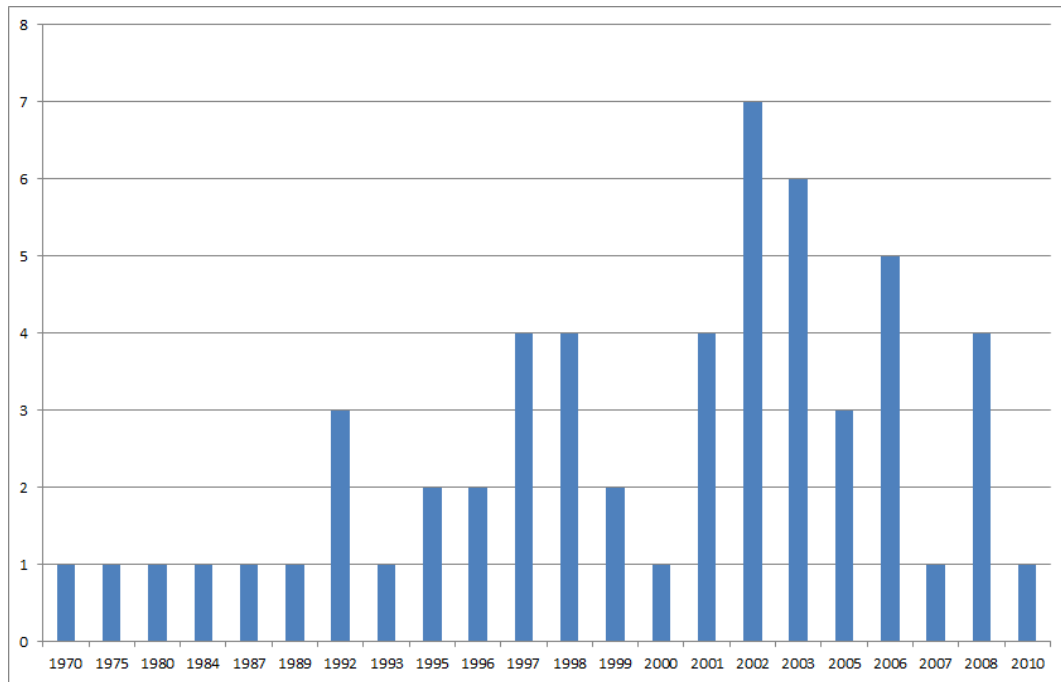


Figure 3. Number of groups according to the year of group's creation.

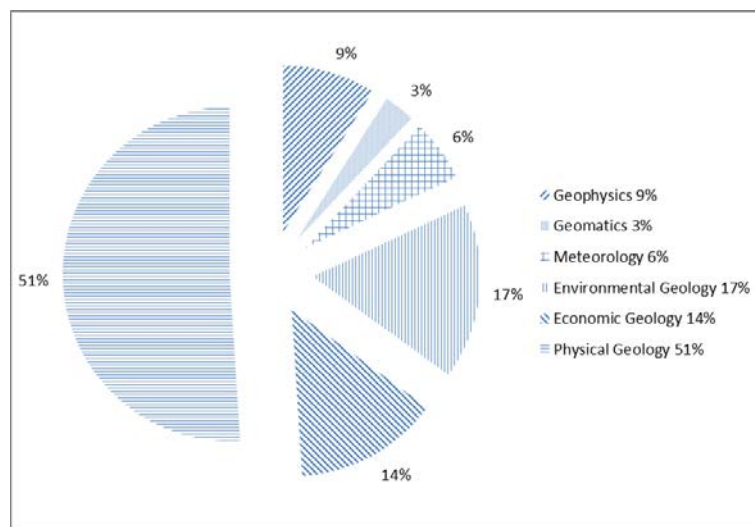


Figure 4. Distribution of the groups based on their fields of interest.

***Classification of groups based on their field of interest***

Figure 4 shows the distribution of the groups based on their field of interest:

***Classification of groups based on the academic level of their leaders***

According to the information registered on the ScienTI Platform, the leaders of the registered groups have the following degrees: postdoctoral, doctoral, master and graduated. The classification of groups based on the academic level of the group's leaders is shown in Figure 5.

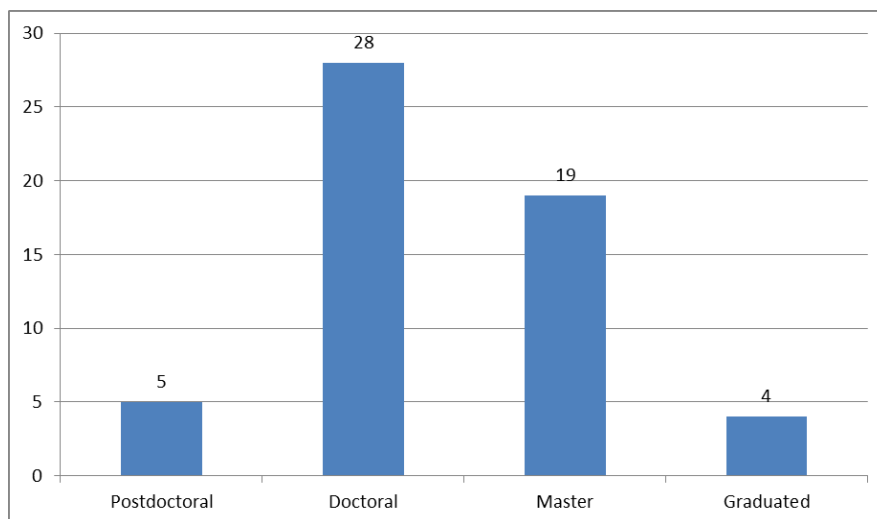


Figure 5. Classification of groups based on the academic level of the group's leaders.

Table 2. Contribution of groups according to their category.

	Articles		Presentation at scientific events		Books		Book's chapters		Thesis	
	Qty.	%	Qty.	%	Qty.	%	Qty.	%	Qty.	%
<b>Groups A and A1</b>	607	27	1254	36	56	18	39	11	514	29
<b>Groups B</b>	257	11	449	13	49	16	73	21	149	8
<b>Groups C</b>	294	13	355	10	87	29	42	12	272	15
<b>Groups D</b>	629	27	1011	29	77	25	123	36	615	35
<b>Acknowledged</b>	504	22	425	12	37	12	69	20	222	13
<b>TOTAL</b>	2291	100	3494	100	306	100	346	100	1772	100

### ***Production of the groups according to their category***

According to GrupLAC<sup>32</sup> the production of the research groups includes: Articles, book chapters, research books, writing thesis or dissertations, grey literature, and other results not certified, results related to the technical services or qualified consulting, products of disclosure and popularization of results obtained from researches, technological products or processes, etc. Nevertheless the products of the research groups are of diverse types, we present here the statistics of the verifiable products only (see Table 2).

Considering the relation between the number of groups of each category and the quantity of products, is clear that the contribution of groups of categories A1 and A is the most relevant.

## **EDUCATION AND JOB MARKET**

In the National Information System of High Education (SNIES<sup>33</sup>) there are 58 academic programs somehow related to Earth Sciences<sup>34</sup>. The classification of the number of these programs, according to the academic level of the programs and their impact level, is presented in Table 3. A preliminary

<sup>32</sup> GrupLAC <http://201.234.78.173:8083/ciencia-war/>

<sup>33</sup> SNIES – Sistema Nacional de Información de Educación Superior (National Information System of High Education of Colombia). [www.mineduacion.gov.co/snies/](http://www.mineduacion.gov.co/snies/)

<sup>34</sup> The results of this search were provided by COLCIENCIAS and the searched words were *Geomatics, Geoinformatics, Earth, Mineral, Cartography, Cadastral, Hydrography, Meteorology, Seismology, Geophysics, Geodesy, Geography, Oceanography, Hydrology, Geology, Tectonics, Structural*.



Table 3. Classification of the number of programs (related to Earth Sciences). The classification presents the number of the programs, according to the academic level of the programs and their impact level (high, medium, low and very low).

	<b>No. of Institutions</b>	<b>High</b>	<b>Medium</b>	<b>Low</b>	<b>Very Low</b>
<b>Technical</b>	2	0	0	1	1
<b>Technology</b>	6	1	1	4	0
<b>Graduate program</b>	16	2	2	4	1
<b>Specialization</b>	25	6	4	4	10
<b>Master</b>	19	8	5	1	2
<b>Doctorate</b>	1	0	1	0	0

analysis of each program's curriculum, based on a Delphi matrix, allowed assessing the contribution level of different programs to the field of Earth Sciences. They are classified by High, Medium, Low and Very Low. The programs with Medium and Low incidence can somehow contribute to the research in Earth Sciences, however, due to the program's contents this contribution seems to be weak.

### **Professional Studies**

Since the aim of this study is analyzing the actual state of Earth Sciences in Colombia, only the programs directly related to the topic and with high incidence are considered. Among them, there are two graduate programs: Geology and Oceanography. Additionally, even if in the search there were not registered the programs of Geological Engineering and Mining Metallurgy Engineering of the National University of Colombia in Medellin campus, they are included as belonging to the field. The five (5) graduate programs, from the Geology field, which are active and full-time tuition programs are offered by the universities: Caldas, Pamplona, EAFIT, UIS, and National University of Colombia.

Between 1987 and 1988, the percentage of aspirants to the Geology program in Colombia was 0.21% of a total. In Bogota the relation of applicants/admitted was greater than 10 to 1. It was slightly less in Medellin, and equal at the Industrial University of Santander (UIS) and at the University of Caldas. The number of students admitted per semester did not pass 30 in each one of these four institutions (Briceño and Mojica 1993). Between 1990 and 1995, the average of admitted students varied, but is mostly around 40 (Espinosa et al. 1998).

In 2008 and 2009, the relation of aspirants to the Geology program to a total number of aspirants was 1% at the National University of Colombia (Table 4). The relation in Mining and Metallurgy Engineering program at the National University of Colombia in Medellin campus was 2%.

Students admitted to the Geology program represented 1% of the aspirants admitted in Bogota. It was 2% in 2008 and 3% in 2009 in the case of the Geological Engineering program in Medellin. A similar situation has happened in the Mining and Metallurgy Engineering program where the percentage was 2%.

At the National University of Colombia, 11% of all aspirants were admitted to the Geology program in 2009 (it is similar to the percentage reported in the late 80's). In 2008, it was 13%. At the same time, the Geological Engineering program in Medellin campus had 60% admitted students.

Briceño and Mojica (1993) state that the results of a survey performed in different universities have revealed a big difference in physical, instrumental and human resources. The average number of full time professors per program was not greater than 15 in most of the cases, and less than 50% of teachers have a postgraduate diploma. By 2010, the numbers became substantially greater.

Table 4. Relation of aspirants to geology profile programs in different universities<sup>35</sup>.

	<b>Program</b>	<b>Total Aspirants per campus</b>	<b>Admitted per campus</b>	<b>Aspirants per program</b>	<b>Admitted per program</b>
<b>2008</b>	Geology National University (Bogota campus)	74,957	5,482	566	74
	Geological Engineering National University (Medellin campus)	11,686	3,305	136	81
	Mining and Metallurgy Engineering National University (Medellin campus)	11,686	3,305	254	74
	Geology Caldas University			989	125
	Geology Industrial University of Santander			260	52
<b>2009 I semester</b>	Geology National University (Bogota campus)	44,064	2,845	355	40
	Geological Engineering National University (Medellin campus)	7,213	1,647	103	46
	Mining and Metallurgy Engineering National University (Medellin campus)	7,213	1,647	142	39
	Geology Caldas University				59

### Postgraduate Programs

At a postgraduate level, there are eight “Master” and five “Specialization” programs (Table 5).

Briceño and Mojica (1993) point out that the lack of postgraduate programs in the field of Earth Sciences means a huge disadvantage in the case of Colombia, and a high economic and social cost, due to the deficit of national experts and the dependence on the right solution of Mining problems, the prospection and extraction of hydrocarbons, Geological Engineering and Environmental Geology (geological risk problems), among others.

### Specialized Laboratories

The Colombian universities are provided with different kind of laboratories: preparation of samples, stereomicroscopy, photointerpretation, petrography, and paleontology. Particularly, the universities: National of Colombia, EAFIT, UIS and Caldas, have academic licenses for specialized software and hardware on petroleum industrial analysis.

Between 2008 and 2010, the National Hydrocarbons Agency (ANH) set up a national project of the Earth Sciences Laboratories Network in order to outfit the universities that have Geology programs with specialized laboratories. The aim of this Project is to increase the number of well-trained specialists nationwide and to offer to universities a possibility to have all the tools for exploration of hydrocarbons. The fact of having a well-equipped laboratory strengthens research, supports the industrial development and expedites country’s economy. The mentioned Project is permanently supported and managed by COLCIENCIAS, and will allow mobility and academic development on a collaborative scenario among all Geology schools.

Donated by ANH specialized laboratories are distributed as follows:

- Industrial University of Santander (UIS) – Geochemistry.
- National University of Colombia, Bogota campus – Geophysics.
- University of Caldas – Stratigraphy.
- EAFIT – Remote Sensors.
- UPTC – Structural Geology.
- University of Pamplona – Petrophysics.

<sup>35</sup> Information taken from the Universities’ statistics reports. [www.admisiones.unal.edu.co](http://www.admisiones.unal.edu.co)

Table 5. Postgraduate programs in Earth Sciences in Colombia<sup>36</sup>.

Institution	Program	City
EAFIT University	Specialization in geology (geological cartography)	Medellin
University Foundation Los Libertadores	Specialization in Geomatics	Bogota
Military University Nueva Granada	Specialization in Geomatics	Bogota
EAFIT University	Specialization in Earth Sciences and Environment	Medellin
EAFIT University	Specialization in Earth Sciences and Environment	Pereira
Naval Academy Almirante Padilla	Specialization in Hydrography	Cartagena
Santo Tomas University	Specialization in Planning and Integral Management of Hydrographic Basins	Bogota
National University of Colombia	Master in Geomatics	Bogota
Industrial University of Santander	Master in Geology	Bucaramanga
National University of Colombia	Master of Science - Geophysics	Bogota
National University of Colombia	Master of Science - Geology	Bogota
National University of Colombia	Master of Science - Meteorology	Bogota
University of Caldas	Master in Earth Sciences	Manizales
EAFIT University	Master in Earth Sciences	Medellin
Naval Academy Almirante Padilla	Master in Oceanography	Cartagena

### Job Performance

The top job sectors are the mining, petroleum and civil engineering. Nevertheless, universities do not incorporate labor needs fast enough and do not recognize, which of the society and company's requirements are circumstantial or and which structural, without their total integration in the redefinition of the programs.

Giraldo et al. (2005) point out that the unemployment rate rises in 3 years up to 7.0% compared with 0% in 2002. It can be explained by the major participation of graduates, who in 2004 were just starting to join the job market, which affected the unemployment in general. The underemployment that distress geologists basically is the lack of working hours (15.8%). It means that the graduates, especially those who work in the fields related to their professional profile, would be able to work more hours per day. In 2005 the underemployment rate is 22.8%, 3.3% greater than in 2002 because, unlike the past study, in which the underemployment rate was concentrated in lack of working hours, actually 2.6% are underemployed due to the competence and 5.3% because of the inadequate earnings.

The majority of the professionals are working in the economic sector, where the labor is related to the graduates' task. 24.5% of them work in the exploitation of mines and quarries, and 20.8% in the educational sector. The average salary per month is equivalent to: 3950 USD for those who work abroad and 1320 for those who reside in Colombia.

The numbers reveal that geologists join the job market easily because 63.7% get a job before or right after the graduation and the majority gets it after 7 months of searching. However, in other fields the average time of job search is 30.4 months, which is 3 times longer than in general (10.1 months); in addition, the job would not correspond to the formation in geology.

The job rotation is more dynamic for those who have their profile related more to the administrative work than with the research one. Therefore, the first group has more mobility

<sup>36</sup> Information taken from SNIES.

(depending on the administrative post) than the second one. Different factors influence these results: few job sources for geologists due to a still incipient development of geological research, the organizational structure of entities where they work and the type of contract.

Geologists perform their postgraduate studies in order to deepen or complement their formation (83.3%). Only 16.9% decide to change the qualification or to extend their work possibilities. Mostly, these are employees of the administrative sector, unemployed or inactive specialists. There are different options of entrepreneurship: the graduates who have changed their profiles founded companies specialized in construction and in wholesale and retail commerce. Those who have conserved their initial formation created consulting companies and companies in the mines and quarry exploitation sector.

## RESEARCH, PUBLICATIONS AND EVENTS

### Funding

Since 1970 until 2010, in the field of Geosciences, in association with different universities, research centers and companies, COLCIENCIAS has co-financed 127 research projects. Table 6 shows the contributions (in USD) of COLCIENCIAS and the other institutions (counterparts).

This amount corresponds to the 2.5% of all projects co-financed in the Basic Sciences National Research Program (according to the report provided by COLCIENCIAS). This amount, destined to Earth Sciences, obviously is not enough to cover the necessities of this strategic research topic. The number of projects co-financed by COLCIENCIAS per year is shown in Figure 6.

As a Technology Development Center for Earth Sciences in Colombia, ECOPETROL has the Colombian Institute of Petroleum (ICP), whose objective is to conduct research, development and to transfer strategic technologies, which allow maximizing the benefit of the operation, and optimal rise of hydrocarbon sector. The projects developed by the ICP are entirely financed by ECOPETROL.

Table 6. Contributions (in USD) of COLCIENCIAS and the other entities to the research projects in Colombia.

COLCIENCIAS	Other institutions (counterparts)	Total
9,240,354	11,911,311	21,151,665

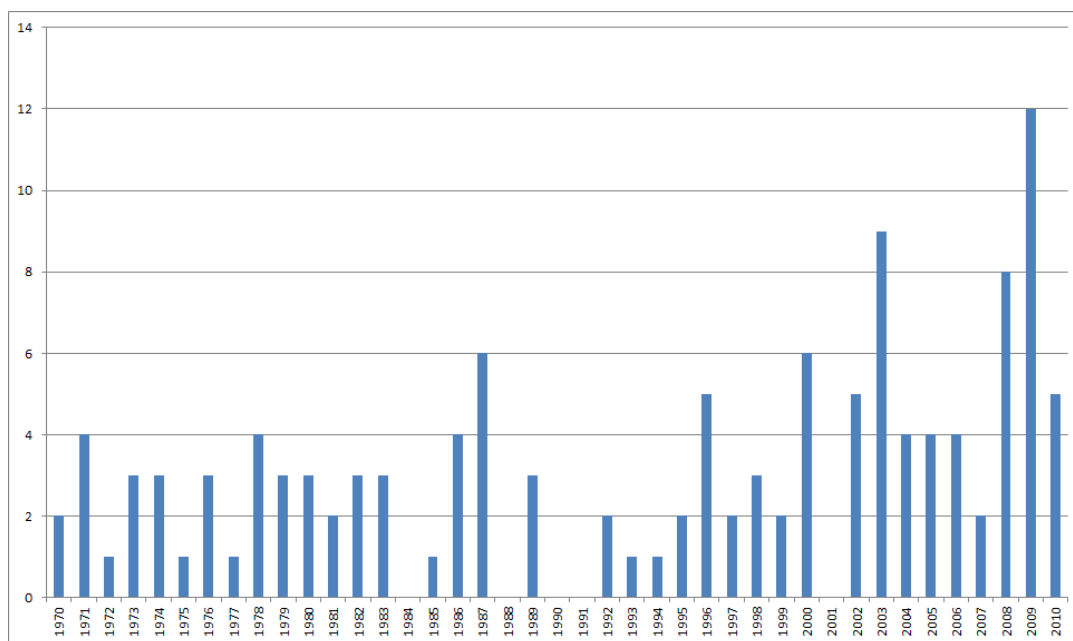


Figure 6. Number of projects, in Earth Sciences, co-financed by COLCIENCIAS per year.

Table 7. Publications in the field of Earth Sciences in Colombia<sup>37</sup>.

ISSN	Journal	Publishing House	PUBLINDEX classification
0012-7353	DYNA	National University of Colombia Medellin campus	A2
0120-5609	Engineering and Research	National University of Colombia Bogota campus	A3
0120-0542	Scientific Bulletin CIOH	Center of Oceanographic and Hydrographic Researches CIOH	A4
0122-9761	Bulletin of Marine and Coastal Researches	Institute of Marine and Coastal Researches José Benito Vives de Andreis, INVEMAR	A
1794-6190	Earth Sciences Research Journal	National University of Colombia	B
0120-0283	Bulletin of Geology	Industrial University of Santander (UIS)	B
0120-3630	Bulletin of Earth Sciences	National University of Colombia	B
0122-5383	CT&F Science, Technology and Future	ECOPETROL S.A. Colombian Institute of Petroleum	B
0370-3908	Journal of Colombian Academy of Exact, Physical and Natural Sciences	Colombian Academy of Exact, Physical and Natural Sciences	B
0121-5701	Advances in Hydraulic Resources	National University of Colombia Medellin campus	C
0121-3423	Scientific Bulletin CCCP	General Marine Direction	C
0120-9833	Energetics	National University of Colombia Medellin campus	C
1794-9165	Engineering and Science	EAFIT University	C
1657-480X	Bulletin of Colombian Energy Observatory	Colombian Observatory of Energy	C
0072-0992	Colombian Geology	National University of Colombia	C

### Publications, information and documentation

At a national level, in Colombia, publications related to the field of Earth Sciences and registered in PUBLINDEX<sup>38</sup> are the following (Table 7).

Of the fifteen (15) Colombian journals classified in PUBLINDEX, only a few have articles by authors from other countries and research results of high impact level. It is important to strengthen the competences at a level of scientific divulgation, in order to be considered as a country where the researchers would like investigate and publishing their results. Therefore, joining efforts and resources of different institutions for one publication could be the most convenient way to be noticed by the international community.

Additionally, we must mention: the Geological Bulletin of INGEOMINAS, which has been publishing the results of the studies performed by this institution since 1953, and the Special Geological Publications of INGEOMINAS, published since 1978 no periodically.

It is necessary to identify the results of researches through the program of technological surveillance by answering questions, such as: where are co-authors of Colombian researchers from?

<sup>37</sup> Data taken from Publindex.

<sup>38</sup> PUBLINDEX – Sistema Nacional de Indexación y Homologación de Revistas Especializadas de Ciencia, Tecnología e Innovación (National System of Indexing and Homologation of Science, Technology and Innovation Specialized Journals). 201.234.78.173:8084/publindex/

Which journals publish their results of research? Who are the most productive authors and in which field?

### Scientific Events

The scientific community organizes different events in Colombia, where researchers meet and show their last results:

- **Colombian Congress of Geology.** This event is organized every two years by different Colombian schools of Earth Sciences with the support of the Colombian Geological Society. Technical scientific developments are introduced through conferences, poster sessions, meetings and forums.
- **Technical week of Geology.** It is an academic event that favors to the integration spaces and divulgation of the student's activities. It is organized every two years, intermittently with the Colombian Congress of Geology, with the support of the Colombian Geological Society.
- **Bolivarian Symposium of Petroleum Exploration of the Sub-Andean Basins.** This event is organized by the Colombian Association of Geologists and Geophysicists of Petroleum every three years. Geologic topics on the exploration of hydrocarbons are considered.
- **Latin American Congress of Seismology and Colombian Congress of Seismology.** Approximately every two years the Groups of Geophysics of the National University of Colombia and the Antonio Nariño University, the Quimbaya Group of the University of Quindio<sup>39</sup>, the Seismological and Geophysical Observatory of Colombian Southwest<sup>40</sup>, with the support of INGEOMINAS through the National Seismologic Network of Colombia, and seismic observatories in Pasto, Manizales and Popayan cities, organize this event in order to advance in the knowledge related to the seismic phenomena and their impact on the society.
- Other events are: Colombian Meteorology Congress; Seminar about the Colombian Quaternary.

## CONCLUSIONS

It is unquestionable that a long road has been run in order to consolidate the Earth Sciences in Colombia. Probably, most of negative aspects detected in the past have been overcome. However, it is necessary to move forward having in mind the following strategic key points:

- Consolidate research groups through the research and publications of high impact level.
- New technological innovation schemes in the field of Earth Sciences should be assessed. Promotion of the interdisciplinarity could help to increase technological production taking in consideration new realities.
- Strategies should be identified in order to close gaps among the State, universities and the productive sector that still exist in some fields.
- Implementation of the National Network of Laboratories must be continued, as well as the new infrastructure with their collaborative use by institutions, stimulating the generation of joint cooperation projects with Colombian research groups and research networks from other countries (state institutions, universities, etc.). It will help also to eliminate the duplicates of research work.
- A graduate program in geophysics has to be consolidated. The petroleum and mine industry demands it and the evolution of new scientific concepts allows it. It is also necessary to promote the creation of advanced formation programs, especially doctorates in Earth Sciences, which integrate more than 50 years of academic history and outline in the future new niches of research of high impact.
- It is necessary to undertake new graduate academic programs, such as Meteorology, in search of incorporating and revitalizing new generations of experts that will be able to investigate some complex topics as Risk Management and Climatic Change.

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<sup>39</sup> <http://blade1.uniquindio.edu.co/>

<sup>40</sup> <http://osso.univalle.edu.co>

## REFERENCES

- ANH – National Hydrocarbons Agency. <http://www.anh.gov.co>
- Briceño, L.A. and Mojica, J. 1993, La Geología y la Geofísica en Colombia: Desarrollo, Estado Actual y Perspectivas. *Geología Colombiana* **18** 161 – 198.
- CAR – Autonomous Regional Corporation of Cundinamarca. <http://www.car.gov.co>
- CHEC – Hydroelectric Central of Caldas. <http://www.chec.com.co>
- CIAF – Research and Development Center for Geographic Information. <http://www.ciaf.edu.co>
- CIOH – Oceanographic and Hydrographic Research Center. <http://www.cioh.org.co>
- COLCIENCIAS – Administrative Department of Science, Technology and Innovation. Republic of Colombia). <http://www.colciencias.gov.co>
- CVC – Autonomous Regional Corporation of Valle del Cauca. <http://www.cvc.gov.co>
- DNP – National Planning Department. <http://www.dnp.gov.co>
- EAFIT – University of Administrative Studies, Finances and Technologies. <http://www.eafit.edu.co>
- ECOPETROL – Colombian Petroleum Company. <http://www.ecopetrol.com.co>
- EIA – Engineering School of Antioquia. <http://www.eia.edu.co>
- Espinosa, A., Lozano, J. y Hermelin, M., 1998, Diagnóstico de las Ciencias de la Tierra en Colombia y Bases para un Plan Estratégico de Desarrollo. COLCIENCIAS, Informe Interno.
- Faculty of Mines of the National University of Colombia. <http://www.minas.medellin.unal.edu.co/index.php/es/>
- Geological Department at the National University of Colombia. <http://www.geociencias.unal.edu.co/>
- Giraldo P.A., Hurtado O.C., López V.C., 2005, Universidad EAFIT: Impacto Social de los Programas de Pregrado, Geología. Oficina de Planeación Integral.
- GroupLac. <http://201.234.78.173:8083/ciencia-war/>
- <http://www.ecopetrol.com.co/especiales/Portafolio%20ICP/portafolio/centro/index.htm>
- IADB – Inter American Development Bank. <http://www.iadb.org>
- ICEL – Colombian Institute of Electric Energy. <http://www.minminas.gov.co>
- ICFES – Colombian Institute for the Foment of the High Education. <http://www.icfes.gov.co>
- ICP – Colombian Institute of Petroleum.
- IDEAM – Institute of Hydrology, Meteorology and Environmental Studies of Colombia. <http://www.ideam.gov.co>
- INGEOMINAS – Colombian Geological Service. <http://www.ingeminas.gov.co>
- Institute of Geophysics Javeriana University. <http://fing.javeriana.edu.co/geofisico/>
- Institute of Natural Sciences. <http://www.icn.unal.edu.co>
- National University of Colombia. <http://www.unal.edu.co>
- OLADE – Latin American Organization of Energy. <http://www.olade.org>
- PUBLINDEX – National System of Indexing and Homologation of Science, Technology and Innovation Specialized Journals. <http://201.234.78.173:8084/publindex/>
- Quimbaya Group of the University of Quindío. <http://blade1.uniquindio.edu.co/>
- RSNC – National Seismological Network of Colombia. <http://seisan.ingeminas.gov.co/RSNC/>
- ScienTI Platform. <http://www.colciencias.gov.co/scienti>
- Seismological and Geophysical Observatory of Colombian Southwest. <http://osso.univalle.edu.co>
- SNIES – National Information System of High Education of Colombia. <http://www.mineduacion.gov.co/snies/>
- UIS – Industrial University of Santander. <http://www.uis.edu.co>
- University of Caldas. <http://www.ucaldas.edu.co>
- UPTC – Pedagogical and Technological University of Colombia. <http://www.uptc.edu.co>