SEG SOCIETY OF EXPLORATION GEOPHYSICISTS

Student Chapter

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About Us

The UERJ Student Chapter was founded in 2015 by undergraduate students in Geology to promote an area of little interest to geologists: Geophysics. Our role is to broker relationships between entities, companies and students so that together we can grow and qualify, both professionally and academically.

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Cover and back cover: Hoover Dam in the states of Nevada and Arizona, USA. Photograph taken from *bit.ly/2GmGs5m*.

Page 11: Photographs taken from *bit.ly/2Uz6Ame*

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Editorial

Geophysics and the orange seed

By Irineu Figueiredo (UERJ-IF-DFAT)

The best explanation I know of geophysics was elaborated by the National Observatory technician Mafra, who died in a car accident during a field trip - who said: “Geophysics is like trying to determine the position of the seeds of an orange without open the orange ”. In this context, the stone is something different within the orange.

In geophysics, differences (or contrasts) in the physical properties of rocks are called **geophysical anomalies**. The search for these anomalies is performed using sensors on the earth's surface capable of measuring the effects produced by these physical properties.

Sensors do not distinguish who produces the effects being observed. That is, the sensor is receiving influence from everything around it. This makes each geophysical method of measurement have its peculiarities. In some cases, it is necessary to remove the effects of anything that conceals the anomaly sought; in others, one looks for another place to measure. A simple example: I'll take a picture of you and an unknown person is next to you. In the first case, I ask the person to move away. In the second, the person does not move away and, as we do not want to fight, you move away to take the picture. Once the unwanted effects are removed, we get an anomaly that will allow us to make assumptions about the distribution of existing subsurface materials.

Thus, geophysical measurements made on the surface must be distributed so that the contrasts can be perceived. In the example of orange, the anomalies would be generated by the seeds, and if the measurement positions are chosen improperly - for example, away from the seeds so that we do not perceive the anomalies - we can come to the wrong conclusion that this orange has no seeds. Therefore, choosing where to take measurements on the Earth's surface is a matter of the utmost importance in geophysics.

Once the anomaly is obtained, the question is where is the seed. Let us try to understand the difficulty in finding it by playing blind man's buff: you are blindfolded next to your colleague; he pulls away and we spin you around. Let's call the colleague **cause** and you **effect**. The cause knows exactly where the effect is; this we call **direct problem**. The cause only sees one effect. On the other hand, you know that your colleague is in any position within a meter of you, but not where he is and this is called the **reverse problem**. That is, in the inverse problem we have several solutions that we say are the **ambiguity** of the geophysical method. The effect can have several causes. To find the colleague you need to be provided with information - go forward, turn left, take another step, etc. The effect needs information to locate the cause. In Geophysics, all information about the region under study and about the constitution of the seed (gold, diamond, water, oil ...) will decrease the number of possible solutions, bringing the result obtained closer to reality.

A good understanding of these three aspects - removal of unwanted effects, distribution of measurement points, and ambiguity - is necessary for a satisfactory result, but not enough. You will have difficulty getting a good result if the measurements are not of good quality. And we must keep in mind that it is expensive to bring the equipment with the sensors to the measurement site. Knowledge of the laws of physics related to the geophysical method, which tell how the cause causes the effect, allows you to take the necessary precautions to perform the measurements satisfactorily. In addition to providing procedures to remove unwanted effects. Knowledge of the geology of the study site helps in choosing the position at which measurements should be made and designing the model that represents the distributions of subsurface physical properties.

These considerations should be in focus regardless of the geophysical method that will be used for quality scientific work. Make good use of geophysics. ■

Interview with Rosemary Silva, HR Specialist, about Resume and Job / Internship Interviews

By Lucas Monteiro

On March 23, 2018 we had the pleasure of welcoming Rosemary Silva, HR professional, who gave the lecture "How to stay interesting for the job market?", where she gave tips on resumes and job / internship interviews. At the same time, she gave us an interview on these topics, which can be seen below.

Lucas Monteiro - Tell us a little about yourself and your career.

Rosemary Silva - I have about 25 years in the market. I have been working in HR for about 15 years, with personnel department, human development and training, which is the area I chose to go into. I am currently a HR coordinator for one group, and in this group, I take care of three companies with three completely different business niches. I have a degree in letters from Gama Filho University. I love what I do, I have a real passion for dealing, treating and being with people.

LM - What are your job prospects, in general, in Brazil, for the next biennium?

RS - Very short term, right? I have been following a very incipient, small, slow growth, but I think it is starting the resumption of employability. We went through an electoral process. We are still at that beginning to realize what the economy will look like, what the real profile of the new economy will look like, what the real profile of the new government is, and it always scares the financial market a little; This consequently affects businesses and companies a bit. But I see with a lot of optimism. I think it is growing and will grow, and the tendency is to improve. I think the crisis, the big crisis, is over.

LM - We're out of the deep end, right?

RS - Yes! Now we start sticking our nose out, thankfully.

LM - What would be the most common mistakes you identify in candidates?

RS - I am even doing some selection processes. So for starters, spelling mistakes. This kills any resume, so avoid it. Another mistake: laziness. For example, when you post a vacancy, you ask some questions, such as, "What is your wage claim?" Or "Talk about your experiences," and the person answers, "It's already on the resume." When asked what your wage claim is, please do not put it up to date. We can talk later about the

Rosemary Silva has been an HR professional for over 15 years, graduated in Letters from Gama Filho University. Provided services to the companies Líder Taxi Aéreo, Estre Ambiental, Petrobras, CCR Ponte and Eco Vias. She is currently HR Coordinator at Imariz Car Rental and Life Rio Emergências Médicas.

value, but inform one. And always be objective, of course. Another terrible problem: untruth. Do not lie in the resume or interview. I think these are the fundamental mistakes, the main ones, actually. Spelling mistake, poorly written resume, tiring resume to read. For example, I apply for a financial analyst job resume, where management experience is required. Then comes a telemarketing analyst and sends the resume. You ask, “Do you have experience?”; “No, but I can learn” ... In short, three points: spelling mistakes, poorly written resume and lack of assertiveness.

LM - What are the biggest complaints you have ever heard from a candidate, or someone has ever spoken to you in an interview?

RS - That is clear. The main thing, you see on social networks, is that the company gives no return.

LM - It's the classic.

RS - This is the classic. Almost 100%. Really, companies give no return, for several reasons. Sometimes, because there were two hundred candidates and only one or two people to do the hiring. Or because there was no time; because it's not the company profile ... I know it doesn't justify, because I've been to the other side too. And it's bad that you go through a selection process and don't know if you passed or not, and if not, why. Or even not knowing if the process is still in progress or has been completed. Because it happens too. Sometimes I open a selection process and halfway the company gives up and asks me to stop. So this is very bad. Lack of return is really the worst complaint. It's something that we, as a company, as HR, are trying to improve. And with colleagues we also say that a lot, "give back". We are on this side today but have been on the other side and may be again one day.

LM - We never know when will be on the other side of the fence, right?

RS - Exactly.

LM - A little bit of humor: What are the weirdest or most bizarre cases you have ever seen?

RS - Wow, that gives a five hours talk ... (laughs). So, for example, we made a driver selection, and the boy filled out the form and simply didn't have a license. None. Then he said he wanted to take it, but it was complicated .... You get a resume - I currently have a pile on my desk - like this: “Do you have experience? " “No, but I can learn ... ”. It's a company, not a school .... "I've never had experience because I've never had a job, I want you to give me a chance because I know I'm capable ...". You see a lot. Things that are picturesque. For example, candidates who go with their mother for the interview .... Comes with his wife because she wants to know how much he will earn. I ask: “Who will come in? "He, but I want to come in too, because I want to know how much he will earn, what are the benefits, what will be the working hours." This is very common to happen. Candidates who in the first interview already want to know when they will take a vacation ..

LM - Wow ...

RS - Yeah. The job is, for example, auxiliary, and the candidate wants to know if he can not fit as an assistant because his resume is very good, and so on .... Just tragedies.

LM - (laughs). Then, just downhill.

RS - Just tragedy.

LM - Briefly, for someone who didn't know anything about the job market or resume, what would you rate as important, what would you say would be a minimally presentable resume?

RS - Your full name, preferably without abbreviation, unless it is somewhat Peter II (former king of Brazil), very long. Never ever put ID or Social Security numbers.

What are we looking for? An objective curriculum. Your name, as its name implies, your career goals, your key experiences concisely, but so that you sell yourself. Let those who read say, "This is what I want." And your key personal information. If you have availability to travel, how many languages you speak, if you are at least advanced, if you have a driver's license, availability to travel. These are all the basic thing. One or one and a half pages is enough.

LM - Being very succinct.

RS - And whatever happens, never send a resume of fifteen, twenty pages, as I already got, because we do not want handouts or books ...

LM - These days I looked at a curriculum on LinkedIn and it had five pages.

RS - No, no, I don't even look. I don't have patience to read it. I discard it at the same time.

LM - What advice would you give to young people trying to get into the job market today?

RS - Don't give up. Everyone had their first job.

LM - First “no”, several “no” ...

RS - Several no, many, many, many, many. Learn how to sell yourself to the market. We seek good professionals, but also that professional who has self-esteem, motivation, disposition. You do not have to sell yourself as if you were the ultimate best. But show what you want. Show excitement. When you go to an interview: "Have you heard about our company?" “Yes, the company does this and that ...". Show that you did your homework right. So for the candidate who is looking for the first job, they have to focus, and can't give up.

LM - Finally, leave a message for our readers.

RS - I repeat, don't give up. Be objective in what you want, and always be the difference, show why you have to get that job, why you have to be in that job and why you have to stay in that job. So show it, be a differencial.

LM - Thank you, Rose!

RS - You're welcome ■

Indirect and Direct Methods Associated with Engineering Works. Why don't we use them and take the risks?

By Marcio Fernandes Leão, of ABGE

The rapid growth of the population not only requires the environment to adapt to the new demands imposed, but also the infrastructure to keep up with this new demand. Between designing and executing a project, many technical studies are fundamental for the knowledge integrated in all its instances to contribute to the success of a work. So could we predict the before, during and after of an engineering project?

Unfortunately, geological materials (soils, sediments and rocks) are uncontrollable. To try to better understand their behavior, software and mathematical models are used that seek the most realistic prediction of the behavior of these materials in relation to the imposed requests. However, there is a threshold between empiricism and reality and, despite the many techniques available and practiced to improve the understanding of the characteristics of these materials, it is essential to understand the evolution of this process against the demands imposed on engineering works. Today a slope is stable, but what about tomorrow? This question must be answered in the various works. How could we prevent and mitigate risks?

Every anthropic action, from building a dwelling on a terrain to excavating a rock mass, imposes changes in the natural state of tensions of a body. Add to this fact processes such as weathering, common in tropical countries, such as Brazil, responsible for degrading the physical, chemical and mechanical characteristics of the substrate, and we will have changes in geological-geotechnical properties, such as resistance, its deformation and permeability, especially when dealing with soft rocks.

Despite all these particularities, is there a way to predict or understand the behavior of geological materials? Yes! With the use of geological-geotechnical research, that has long been used and widespread in engineering works of all magnitude, representing about 0.5% to 2% on average of the overall budget of a Brazilian project. Seems little? It is little, especially considering such grand works, such as dams and tunnels, whose collapse can take many lives and generate environmental, economic and social disturbances.

For any research schedule we need to answer questions such as: “Why investigate?”, “What to investigate?”, “Where to investigate?”, “How to investigate?”, “What are the projected levels and criteria?” and “What steps to take if the established levels are exceeded?”.

The amount and types of investigations to be used varies according to the objective and safety regarding the knowledge of soils and rocks existing in the implantation sites, especially if they are outcrops. When rocks and soils are in the subsurface, the difficulty in obtaining knowledge increases, requiring techniques that enable such information to be obtained.

Thus, the research methods are combined with a drilling program, which has its locations and activity schedule defined, indications of places for sampling and, by chance, *in situ* tests, requiring any adaptation to the needs, both in quantity and in depths to be reached.

These subsurface geological-geotechnical investigations are premises for any engineering project, regardless of their magnitude, that seek to identify the nature of existing geological materials on the ground. That is, they are used both in petroleum engineering or mining projects, where it is usually necessary to drill with large spacing between, as they seek prospecting objectives, as well as in civil engineering projects, where, even when the objective is the construction of large dams and/or deep underground works, the perforated lengths are much smaller, with about 200 m spacing.

The research campaign is supported by data such as aerial photographs, field observations and indirect methods. Investigations should follow standardized norms and records for terminology and symbology, and are present at various stages of any project.

In this context of indirect methods, geophysics has been increasingly highlighted in geotechnical engineering projects. Overall, it has numerous advantages related to wide range, fast data processing and lower cost compared to direct drilling campaigns, attracting top designers.

Geophysical prospecting is based on the determination of force fields, natural or artificial, which are measured on the surface by instruments. The purpose of this research is to obtain data on the spatial distribution of soils, rocks and subsurface structures and to obtain in-depth data on certain physical-chemical properties of the subsoil layers or the variation of such property.

Among the geophysical methods, the electrical and radioactive records are highlighted, especially in engineering works and in the use for mineral prospecting, because they have fast results and low cost. In these methods, drilling can be used to correlate information, but it is not always necessary. These methods are used when a rapid and approximate solution to certain geotechnical problems is required in a given area (hard rock depth for the foundation of a dam, for example).

Seismic methods are also used in engineering works, but mainly in hydrocarbon prospecting, due to their high resolution and depth of investigation, despite the high costs.

On the other hand. the gravimetric and magnetic methods, for example, are less used in civil engineering works when compared to the seismic method and resistivity. The main reason this application is little used is that these methods are more difficult to interpret quantitatively than the propagation velocities in different seismic horizons or the resistivity signatures in rocks and soils. But there are cases where gravimetric and magnetic methods may be the only ones suitable for a particular purpose. For example, the magnetic method is quite appropriate for delimiting intrusive dikes and the gravimetric method can be employed in the search for underground channels or caves.

In the end, should one investigate directly or indirectly? The answer lies in combining the methods, making traditional campaigns more rational, optimized and more consistent data. Properly investigating a work doesn't mean 100% success, but it does ensure that many decisions can be made at minimal risk. We constantly see geological-geotechnical problems related to erroneously dimensioned campaigns, either due to the mistaken adoption of the method or even the lack of knowledge about the increasingly modern techniques.

There is no more opportunity today for trial and error, or random hit. When this moment occurred in the history of engineering, professional effort allowed many areas, such as engineering geology and geotechnical engineering, to evolve technically.

Today we have increasingly advanced knowledge and resources, including geophysical methods. Running a project or even abandoning it, not using the available tools for parameter clarification is taking the risk. Submitting this project under the continuous action of geological-geotechnical processes, based purely on “luck”, is not only irresponsible; it's criminal! ■

UERJ represents Brazil in IBA 2019 semifinal

The UERJ team was selected among six Brazilian teams (UERJ, UFPE, UFPR,UFRGS, UFRJ, UFS) that participated of the Imperial Barrel Award 2019 competition, organized by AAPG (American Association of Petroleum Geologists), reaching the semi-final, which took place on April 6, 2019 in the city of Rio de Janeiro, competing with the *Universidad Industrial de Santander* (Colombia), *Universidad Central de Venezuela* (Venezuela) and the *Universidad de Buenos Aires* (Argentina), in the Latin America and Caribbean Regional.

IBA is an annual global competition for geoscience students where each participant team analyzes geological, geophysical, geochemical and production data of a sedimentary basin during an eight week period. Each team presents the results of their studies in a 25-minute presentation to a group of experts. University teams compete to earn scholarship funds for the universities Geosciences Department and international recognition that comes from participating and, especially, winning the competition.

Announcement of the finalists of the Latin America and Caribbean regional, which went to the IBA 2019 semi-final

The UERJ team was composed by the undergraduate students Giovanni de Oliveira Eneas, Isabela Dantas de Albuquerque, Ricardo Campos Alevato and Vanderson Ribeiro de Assis Lima, and by the master student in Sedimentary Basins, Vinícius Luiz da Silva.

The UERJ team just before the semi-final presentation. From left to right: Vinícius Luiz da Silva, Giovanni de Oliveira Eneas, Isabela Dantas de Albuquerque, Ricardo Campos Alevato and Vanderson Ribeiro de Assis Lima.

At the beginning of January, we received 2D seismic, well and geochemistry data of the Bristol Bay Basin, located at north of the Alaska Peninsula. Over the next eight weeks, we studied this data and were able, at the end of the work period, to synthesize the geology of the area, define its petroleum system and its characteristics, interpret the seismic and well log data, and define a promising lead and the risks associated with a possible exploration activity in the basin.

For the UERJ's Geology course, to get at this stage of the competition, at which was victorious in 2013, represents a recognition of the potential of faculty and students, who, despite suffering from the scrapping of government in recent years, shows that the free public education of our university continues with the same quality and determination, resisting any problem or situation.

We would like to thank all of those who has helped and supported during the months of work: our advisor Hernani Chaves and our co-advisor Marcus Berao; Ana Paula Pires, from Petrobras; Julio Kosaka and Maria Clara Lima, both from Schlumberger; the faculty of the UERJ Department of Stratigraphy and Paleontology (DEPA) Egberto Pereira, René Rodrigues and Sérgio Bergamaschi; to colleagues and friends from geology undergraduate degree class of 2014, especially Felipe Corrêa and Milena Barcelos, and from UERJ master degree Ana Carolina Araújo, Luciana Brelaz, Suelen Gouvêa, Talissa Mira and Vitor Schuback.

We take this opportunity to congratulate the *Universidad Industrial de Santander* team, who will represent Latin America in the final, which will take place on May18, in San Antonio, Texas, and we hope for their victory. ■

Photo taken from AAPG Young Professionals Brazil Linkedln page

UERJ team receiving the certificates of participation in the competition, with Mayra Vargas (left) and Daiane Cardoso (right), coordinators of AAPG Latin America and Caribbean Region, and Hernani Chaves (middle), AAPG UERJ student chapter advisor.

Photo taken from AAPG Young Professionals Brazil Linkedln page

The competing teams, judges and organizers of the IBA 2019 semi-final.

Translation: Daniella Cristina Blanco Silva

Technical Article

Regional characterization of geothermal gradient and heat flux in the state of Tocantins, Brazil: Implications for geothermal resource evaluation

Descovi, P.L.M[1]; Vieira, F.P.[1]; Hamza, V.M.[1]
[1]National Observatory

ABSTRACT

Geothermal energy is emerging in the face of current energy, economic and environmental problems. The region where the state of Tocantins is located, known as Central Brazil, has a complex geology with different geological events such as subduction between the Amazon and San Francisco craton, inheriting the suture zones: Brasilia and Araguaia. These processes are promising scenarios for heat accumulation forming important geothermal reservoirs, possible targets for exploration, confirmed in over temperature maps. Estimates indicate that the resource base amounts to over 1900 GJ. The recoverable portion of the resource is estimated to have values greater than 100 GJ. This estimate is consistent with the current understanding of local geological structures and recoverable energy according to the physical properties of the environment.

INTRODUCTION

The progress made in geothermal studies in Brazil has been discussed for decades in several previous studies (Hamza et al., 2005 and 2010; Vieira et al., 2015). The present work aimed the thermal characterization of the crust under the compartmentalization of the state of Tocantins and identification of geothermal targets of interest for future geothermal energy explorations, uniting regional geology and geophysics.

GEOLOGICAL AND GEOPHYSICAL CONTEXT

The state of Tocantins is located in central Brazil in an area delimited by the neoproterozoic structural provinces Parnaíba, Tocantins and São Francisco (Almeida et al., 1977). These units present evidence of collisions between the Amazon and San Francisco cratons along tectonic suture zones, known as the Brasilia and Araguaia folding belts (Valeriano, 2008; Schmitt et al., 2018).

Regional tectonics is marked by the Quaternary fault systems of Estrondo (BR12) and Porangatu (BR19), as well as Araguaia-Tocantins and Transbrasiliano lineaments (Saadi et al, 2002). In the South region there are important transcurrent faults and the Mara Rosa Magmatic Arc, remnant of the subduction Neoproterozoic events (Almeida, 1986; Brito Neves, 2014), known as the Goiás-Tocantins Seismic Zone - ZSGT (Fernandes et al., 1991 ; Assumpção et al., 2014) (Fig. 1). In the southern region, there are indications of carbonic fluids, defended by several authors (Coelho and Moura, 2006; Padilha et al., 2013; Abdallah, 2016; Solon et al., 2018), so that the carbon would have deposited in a restricted oceanic environment and subsequently metamorphosed and subducted to the mantle, transforming it into graphite under pressure and temperature conditions

MATERIALS AND METHODS

Geothermal data were obtained from wells in 140 locations (Fig. 1). Among these, 37 wells profiled by the Geothermal Laboratory of the National Observatory - LabGeotON (Vieira and Hamza, 2012), 94 wells with geochemical analysis for indirect temperature estimates obtained by the Geological Survey of Brazil (SGB / CPRM) and the other wells are located. in adjacent states, Pará (LabGeotON's profiles), Maranhão, Bahia and Goiás (Petrobras' profiles). The geothermal gradient was calculated using methods classified as Incremental Temperature Logger (ITL), Stable Bottom Temperature (SBT), Bottom-Hole Temperature (BHT) and Geochemical (GCL).

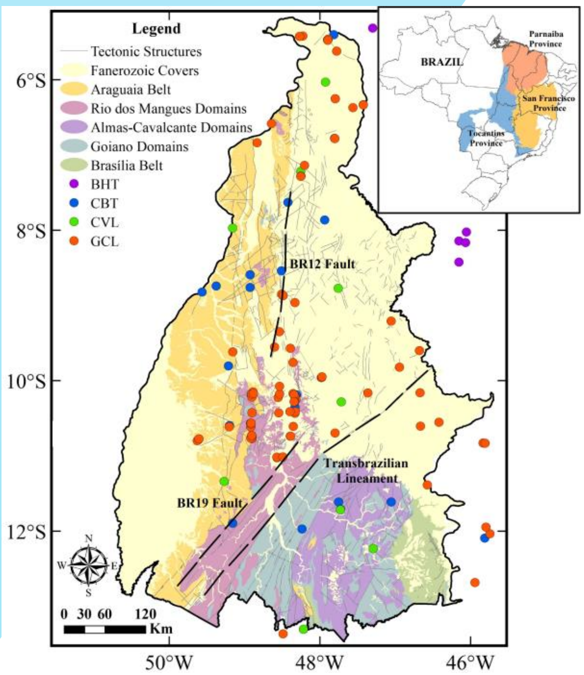

Figure 1 - Simplified geological map of the study area indicating relative locations of major structural features.

The method designated as conventional or Interval Temperature Logger (ITL) is applied for cases where geological layers are homogeneous. Its calculation is determined by the linear adjustment of temperature measurements (Ti) at discrete depth intervals (Zi) when the disturbance does not occur or is negligible. Thus, the gradient is the angular coefficient of the line as follows:

$$grad = \frac{N\sum z_i T_i - \sum z_i \sum T_i}{N\sum {Z_i}^2 - (\sum z_i)^2}$$

The method known as Stable Bottom Temperature (SBT) is used in cases where there is fluid movement in the well. In this way, the disturbed measurements are discarded and only the generally stable bottom measurement is considered. Its calculation is made by the difference between the annual mean surface temperature and the stable wellbore temperature over depth as follows:

$$grad = \frac{T_{CBT} - T_O}{Z_{CBT} - Zo}$$

The method known as Bottom-Hole Temperature (BHT) which is widely used in the hydrocarbon industry is calculated as:

$$grad = \frac{T_{BHT} - T_O}{Z_{BHT} - Zo}$$

So the TBHT was corrected as corrections suggested by AAPG (1976).

The geochemical method (GCL) represents an indirect way to estimate the reservoir temperature of geothermal fluids. Dissolved solute content in hot spring waters is generally used to estimate dissolution temperatures, usually silica, as follows:

$$grad = \frac{T_{GCL} - T_O}{Z_{GCL} - Zo}$$

Where T_{GCL} is the reservoir temperature and Z_{GCL} is the reservoir depth, calculated according to Alexandrino and Hamza (2018).

Thermal conductivity values were obtained from experimental measurements (Vitorello, 1978; Vitorello et al., 1980) and representative for different lithologies (Schön, 2015; Yang, 2017). For each well, a weighted average value is calculated according to the lithologies present in the well. The values found are in the range from 1.07 to 4.7 W/m/K.

The determination of geothermal flux corresponds to the product of thermal conductivity (λ) by the geothermal gradient of the interval ($\partial T/\partial z$), according to the relation:

$$q = \lambda \frac{\partial T}{\partial z}$$

Where q is the flow density per unit area in mW/m2; λ is the thermal conductivity in W/m/K and $\partial T/\partial z$ is the geothermal gradient in °C/Km.

RESULTS OBTAINED

GEOTHERMIC GRADIENTS AND HEAT FLOW

Values for the geothermal gradient (Fig. 2) in the 30 to 60°C/km range were found in the southern region (notable for the presence of magmatic arc features) and in the north-central region (Araguaia Range and Fanerozoic sedimentary sequences), parts of Tocantins Province. Gradient values lower than 25°C/km were found in the Jalapão area, located in the northeast part adjacent to the São Francisco craton.

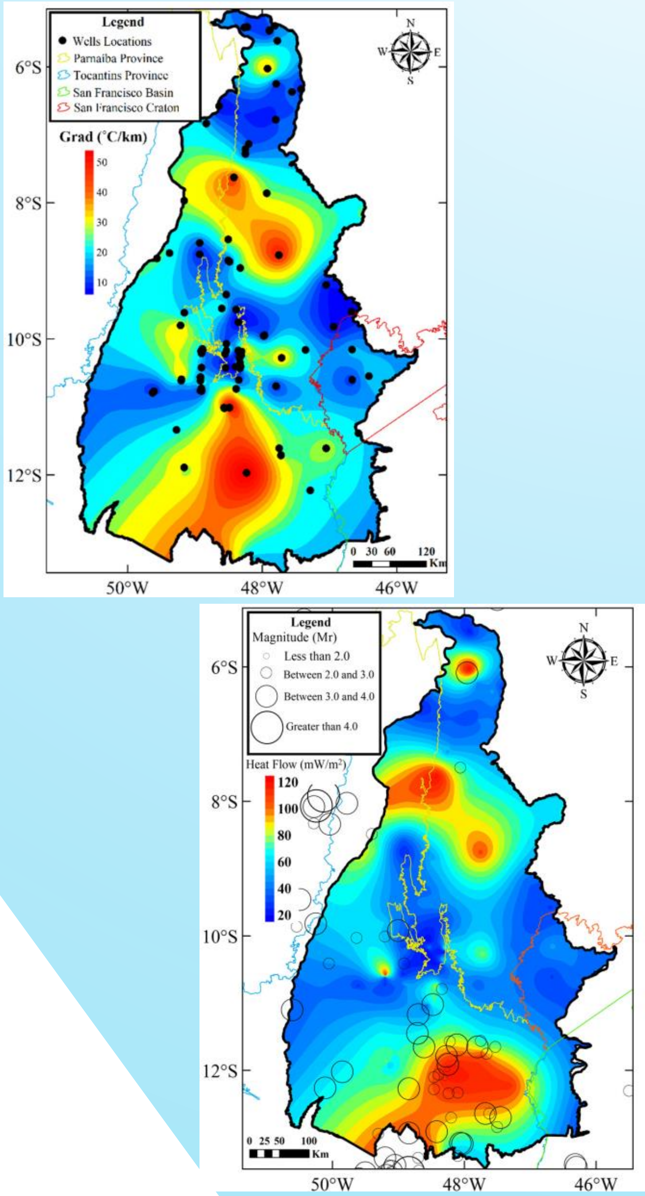

Figure 2 - Regional distribution of geothermal gradients (left) and heat flux (right). Fine curves indicate geological provinces.

Heat flow values in the range of 70 to 100 mW/m2 were found in the same regions (Fig. 2). Note that areas of high heat flux occur in the southern and northern parts and are characterized by moderate seismic activity.

CRUSTAL TEMPERATURES

The temperatures at the crustal depths were calculated assuming a vertical dimensional flow of heat (q) and constant thermal conductivity (λ) from each well. Radioactive surface heat generation (Ao) was assumed with an exponential decrease factor (D). For D, the average value of 11 km was adopted (Alexandrino and Hamza, 2018) and for heat generation the values 2.1 µWm-3 for Archean terrain and 2.3 µWm-3 for phanerozoic. Under these conditions, the ratio of excess temperature (Δ**T**) to depth (z) in the crust is:

$$\Delta T = \frac{A_0 D^2}{\lambda}\left(1 - exp\left(-\frac{z}{D}\right)\right) + \frac{(-A_0 D + q_0)}{\lambda} z$$

Excess temperatures at depths of 3 to 6 km ranged from 25 to 290°C (Fig. 3). Areas with temperatures from 100 to 140°C occur at depths of 3 km in the southern and northern regions. Such regions may have low enthalpy geothermal resources, according to the classification of Muffler and Cataldi (1978), where temperature values below 90°C can be considered low enthalpy, values between 90 and 150°C, average enthalpy and values above 150°C, high enthalpy. Therefore, at depths of 4 km, the resources are classified as high enthalpy. At depths greater than 6 km, thermal anomalies reach values above 250°C.

GEOTHERMIC RESOURCE ASSESSMENT

The volumetric method was employed in the resource evaluation. The study region was discretized using three dimensional cells. This procedure allowed the calculation of the resource base (all available energy). Estimates of

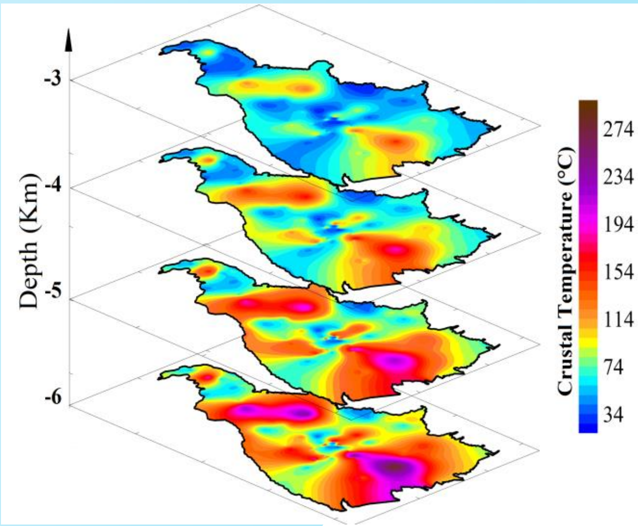

Figure 3 - Excess temperature mapping for 3 to 6 km, in Celsius degrees.

recoverable resources per unit area were made assuming porosity values that decrease exponentially with depth.

The base resource (QRB) is calculated using the ratio:

$$Q_{RB} = \rho\, C_p S \left[\frac{A_0 D^3}{\lambda}\left(exp\left(-\frac{z}{D}\right) - 1\right) + \frac{A_0 D^2}{\lambda} z + \frac{(-A_0 D + q_0)}{2\lambda} z^2\right]$$

Where the expression within the parenthesis is the integrated excess temperature as depth (z), ranging from 3 to 6 km. Some constants are taken into account as average crust density (ρ), approximately 2650 kg/m3; the volumetric thermal capacity (Cp), approximately 836 J/kg/°C; and area S (m^2), obtained from the total area of Tocantins by the number of wells (140), approximately 1,956.109 m^2.

Geothermal resource base values for the 3 to 6 km depth range range from 170 to 2060 GJ/UA (Fig. 4). At depths of 4 km its value is 1000 GJ/UA. For greater depths the value is 1800 GJ/UA.

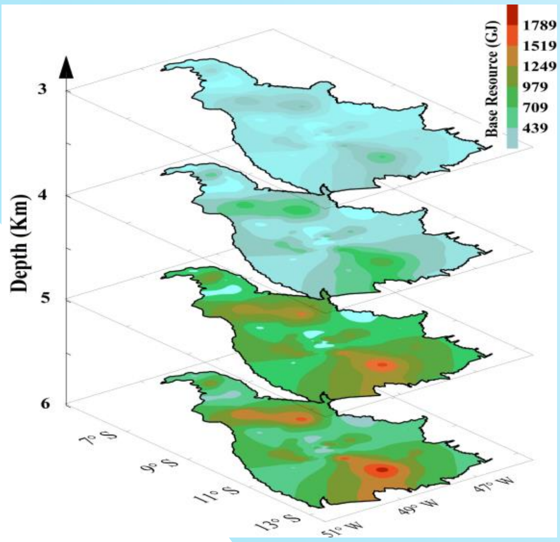

Figure 4 – Stacked view of resource base maps for 3 to 6 km, in units of gigajoules.

The recoverable portion of the resource base (QRR) was calculated using the ratio:

$$\boldsymbol{Q_{RR}} = \boldsymbol{Q_{RB}} * \left[\emptyset_0 * \boldsymbol{exp}\left(-\frac{\boldsymbol{z}}{\boldsymbol{D}}\right)\right]$$

Where porosity is a function that decreases exponentially with the depth of its initial value.

Recoverable features for depth intervals of 3 to 6 km range from 8 to 115 GJ (Fig. 5). The areas of interest are still the same, but the increase in heat content with depth is partially offset by the decrease in porosity.

DISCUSSIONS AND CONCLUSIONS

An assessment of geothermal resources was made in the state of Tocantins, a region of complex geology located in Central Brazil, inherited from regional quaternary and seismic faults (mainly in the southern region), promoting an important geotectonic framework and suitable for observed geothermal energy accumulations.

Heat flow anomalies were found in the over temperature analysis at depths of 3 to 6 km, where low enthalpy resources were observed at depths of 3 km, average characteristics tending to enthalpy at 4 km depth and high enthalpy at 6 km. km deep. in this case, reaching temperatures above 270°C.

Available energy calculations with base resource mapping were estimated and large energy availability was observed in anomaly regions, so that up to 4 km available energy is approximately 1000 GJ and at depths greater than 5 km can reach 1900 GJ in the regions. anomalous and can recover 100 GJ of all available energy, according to maps of recoverable resource.

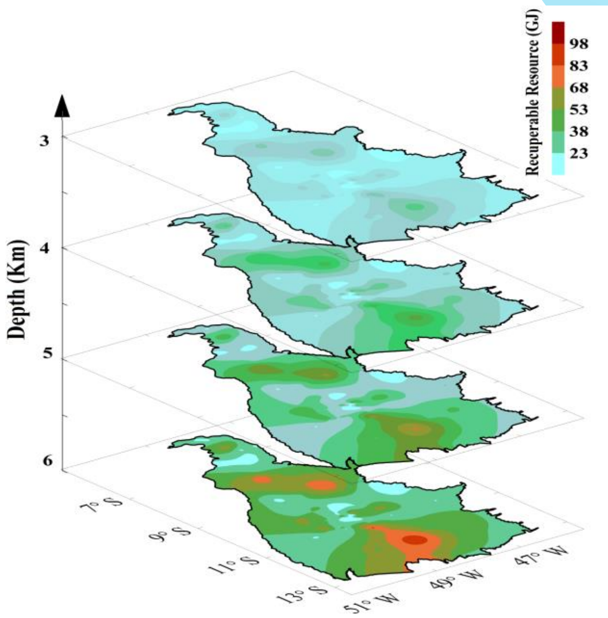

Figure 5 – Stacked views of recoverable resource maps for depths of 3 to 6 km, in gigajoules.

REFERENCES

Alexandrino, C., & Hamza, V. (2018). Terrestrial Heat Flow in Non-Thermal Ground Water Circulation Settings of Brazil. International Journal of Terrestrial Heat Flow and Applications, 1(1), 46-51.

Abdallah, S. (2016). Geologia e Geoquímica do Grupo Riachão do Ouro na Folha Arraias: Evidências de Arco Magnético Paleoproterozóico. Geochimica Brasiliensis, 29(2).

Almeida, F. D., Hasui, Y., Brito Neves, B. D., & Fuck, R. A. (1977). Províncias estruturais brasileiras. Simpósio de Geologia do Nordeste, 363-391.

Almeida, F. D. (1986). Distribuição regional e relações tectônicas do magmatismo pós-paleozóico no Brasil. Revista Brasileira de Geociências, 16(4), 325-349.

Assumpção, M. et al., 2014. Intraplate seismicity in Brazil, in Intraplate Earthquakes, Chapter 3, ed. Talwani, P., Cambridge Univ. Press.

Brito Neves, BBD, Fuck, RA e Pimentel, MM (2014). A colagem brasileira na América do Sul: uma revisão. Revista Brasileira de Geologia, 44 (3), 493-518.

Coelho, C. V., & Moura, M. A. (2006). Mineralizações de Sn do Maciço Granítico Serra Branca, Goiás: evolução do sistema hidrotermal e fonte dos fluidos. Revista Brasileira de Geociências, 36(3), 513-522.

Fernandes, E. P., Blum, M. L. B., & Ribeiro, R. K. (1991, October). The Goias Seismic Zone-A New Approach. In 2nd International Congress of the Brazilian Geophysical Society.

Hamza, V.M.; Silva Dias, F.J.S.; Gomes, A.J.L.; Terceros, Z.G.D. (2005). Numerical and Functional Representations of Regional Heat Flow in South America. Physics of the Earth and Planetary Interiors, Volume 152, 4, p.223-256.

Hamza, V.M., Cardoso, R.R., Gomes, A.J.L. and Alexandrino, C.H. (2010) Brazil: Country Update. Proceedings of the World Geothermal Congress, Bali, 25-29 April 2010.

Padilha, A. L., Vitorello, I., & Pádua, M. B. (2013). Deep conductivity structure beneath the northern Brasília belt, central Brazil: Evidence for a Neoproterozoic arc-continent collision. Gondwana Research, 23(2), 748-758.

Valeriano, C. D. M., Pimentel, M. M., Heilbron, M., Almeida, J. C. H., & Trouw, R. A. J. (2008). Tectonic evolution of the Brasília Belt, Central Brazil, and early assembly of Gondwana. Geological Society, London, Special Publications, 294(1), 197-210.

Vieira, F. P., & Hamza, V. M. (2012). Fluxo Lateral de Águas Subterrâneas nas Bacias Sedimentares: Implicações para Ocorrências de Recursos Geotermais. In V Simpósio Brasileiro de Geofísica.

Vieira, F. P., Guimarães, S. N., & Hamza, V. M. (2015). Updated assessment of geothermal resources in Brazil. In 14th International Congress of the Brazilian Geophysical Society & EXPOGEF, Rio de Janeiro, Brazil, 3-6 August 2015(pp. 480-485). Brazilian Geophysical Society.

Saadi, A., Dart, R. L., & Machette, M. N. (2002). Map of quaternary faults and lineaments of Brazil. Project of international lithosphere program task group II-2, major active faults of the world, University of Minas Gerais and US Geological Survey.

Schmitt, R., Fragoso, R., & Collins, A. S. (2018). Suturing Gondwana in the Cambrian: The Orogenic Events of the Final Amalgamation. In Geology of Southwest Gondwana (pp. 411-432). Springer, Cham.

Schön, J. H. (2015). Physical properties of rocks: Fundamentals and principles of petrophysics (Vol. 65). Elsevier.

Solon, F. F., Fontes, S. L., & La Terra, E. F. (2018). Electrical conductivity structure across the Parnaíba Basin, NE Brazil. Geological Society, London, Special Publications, 472, SP472-19.

Vitorello, I., 1978. Heat flow and radiogenic heat production in Brazil, with implications to the thermal evolution of continents, Univ. of Mich., Ph.D. dissertation, Ann Arbor, 1978.

Vitorello, I.; Hamza, V. M.; Pollack, H. N.,1980. Terrestrial Heat Flow in the Brazilian Highlands, Journal of Geophysics Review, vol. 85, pp. 3778-3788, 1980.

Yang, S., & WEI, J. (2017). Fundamentals of Petrophysics. Springer Berlin Heidelberg.

Collection *Algorithms and Programming Logic*

Technical Article 3: Data, Variables, Expressions, and Operators

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Following the theme of the technical article of the magazine's previous issue, we will now analyze data.

Data is nothing less than the information itself. It can be given by the user using the program, by the programmer, or by instructions according to the programming performed. **Instructions** are the logical orders we give the program so that it generates structures or functions.

Many people who are not computer-minded ignore the value of data and synthesize the machine just by handling numerical data. However, we may have other data types, such as logical or boolean and literals. With them, a range of combinations fills the variables. **Variables** are defined by rules in Boolean logic and should be very well described at the time of writing the algorithm. Much of the error involving programming is in the declaration of both global and local variables. A variable consists of three attributes: a name, an associated data type, and the information it stores.

Finally, variables relate to selection structures, repetition, for example, through Boolean Logic that constitutes relationships between possible combinations of propositions that can only assume two values: 1 or 0. **Logic** is nothing more than primary structure of programming and machines, which by combining these two values assumes a range of possibilities with the use of logical and mathematical operators.

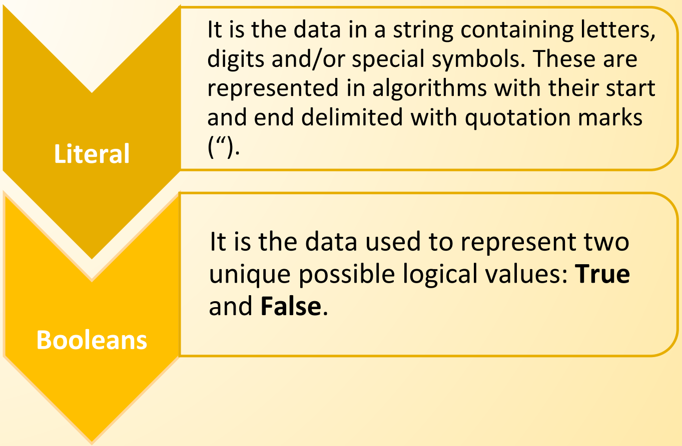
At the end of this chapter, you should be prepared to declare variables that are organized and focused on their true functions, clearly and cohesively. In addition, you should be able to elaborate questions using mathematical logical reasoning, focused here in this course, on the development of programs in Pseudocode. However, this development is intended to enhance any programming languages you may use. As already mentioned, we know that having defined the concept of the algorithms, the programming starts to be developed in a logical way, requiring only adaptations to the worked language.

DATA

The data is divided into four types, each focused on a type of job:

Numeric Integer: It is the data that can be measured for whole amounts, which can be positive or negative.

Numeric Real: It is the data that can have decimal or fractional components and can also be positive or negative.



Numeric Data

Numerical data, as its name implies, are represented by numbers. Numbers, according to the theory of numbers and sets, are divided into:

- Set of **natural numbers (N)**, given by numbers greater than 0 and positive. For some streams of mathematicians, the number zero is not a number contained in this group, so there is a philosophical discussion surrounding this question. This, however, changes nothing for our course.

  N = {1,2,3,4,5, ...}

- The next set is of the **integer numbers (Z)**, which encompasses all numbers from negative infinity through zero to positive infinity. Thus we can say that the set (N) is contained in the set (Z).

  Z = {..., -4, -3, -2, -1, 0, 1, 2, 3, 4, ...}

- Comprising the set of integers is the set of **fractional numbers (Q)**, this set being defined by a quotient where the numerator and denominator are integers.

  Q = {*p* / *q* : *p*, *q* belong to ***Z***}

- In parallel, there is the set of **irrational numbers (I)**, these numbers are referred to real numbers that are not rational, that is, the quotient is not given by whole numbers.

  I = {3.1428 ... (PI); 1.6418 ... (EULER)}

- Comprising all numbers in these sets is the set of **real numbers (R)**, which is the ratio of all fractional and irrational numbers.

  R = {Q ^ I}

In the algorithms, we declare the variables in two groups: the integer variables and the real variables. Let us now know the other types of information that make up the variables.

Literal Data

These consists of a string containing letters, digits and/or special symbols. It is also often referred to as an **alphanumeric string**. Literal data is usually delimited at the beginning and end with the quotation mark (‘’) character. For character information to use when working with lists: the length of a given literal is the number of characters contained in the variable.

Ex:

“Say Your Name” - Length 13 (Space is one character)

“Andréia” - Length of 7

“&% $ @ # *% $” - Length 8

“18.95” - Length of 5

Logic Data

Logic, from the Greek, meaning *the science of reasoning*, is the part of philosophy that deals with the forms of thought in general and the intellectual operations that aim at determining what is true or not.

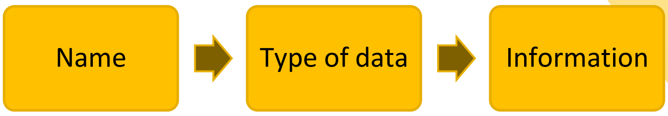
This type of data is somewhat related to the way computers work. They are called Booleans and are used to represent the only possible logical values: **True** or **False**. We may have the list of other attributes such as:

Yes/No; **1/0**; **On/off**. We will soon work on the relations of the logical operators within the reasoning of the algorithm.

Within an algorithm we can find two different classes of data, the **constant** data and the **variable** data. A data is a constant when its value does not change over the time the algorithm is executed, remaining the same from the beginning to the end of the program execution. Data that can have its value changed during code execution is called a **variable**.

Variables

As we saw earlier, variables are divided into three characteristics:



Already knowing the data types that variables can assume, then let's work with another property of variables: the name. Names generate major conflicts within the declaration of variables, as these names have specific rules to declare and to be considered as valid variables:

- It must always start with a letter;
- It must not have blank spaces (Space or backspace - As a solution the underline symbol "_" should be used);
- It must not contain special characters such as numbers or symbols;
- Care must be taken not to use reserved words, ie keywords in the programming language itself, such as commands, variable types, lists, and so on (see Table 1).

Ex:

Lightning; Name surname; F; Horizonte_Reserv; Granite_Cassi.

Always remember that, when creating variable names, preference should be given to mnemonic names, i.e. those that make it clear as to what the variables are defined or what they represent, enabling better documentation of themselves, than using random names like N and X or Y.

Table 1: Examples of reserved words.

Abs	Algorithm	Until
And	While	Then
End_if	Frac	Start
To	Stop	Step
Sen	Else	Tan
Constants	Cos	Of
Do	End	End_while
Read	Literal	Logic
Real	Repeat	Rest
Variables	True	False
Compr	Root	Stop_to
Write	Trunc	Matrix
Integer	Div	If

Declaration of variables in algorithm

Throughout the program, the data will be manipulated through the name of its identifier. The definition of data in algorithms is also known as **declaration**.

An identifier must be declared with a given data type, being restricted to that value, and if there is an attempt to assign a different data to which the identifier has been defined, errors of compilation, execution and even variable data loss will occur.

There are, however, programming languages that do not require type definition to work with data, such as *Python*. These languages are classified as **untyped** and usually accept data assignment of various types to the same identifier.

In Pseudocode, all rows of data must be terminated using semicolons (;). By declaring a variable identifier, we are reserving in computer memory a space to store values of the declared type.

var
<Identifier1>, <Identifier2> ...: <Type1>;
<Identifier3>, <Identifier4> ...: <Type2>;

Ex:

var Block, Company: character [10];
price: real;
Year, Estimate_Production: Integer
constant Max = 100

Note that in the example above, four variables were declared:

- **Block** and **Company** variables, capable of storing literal data information up to a maximum of 10;
- **Price** variable, capable of storing real type numeric information;
- **Year** and **Estimate_Production** variables, capable of storing numeric information of the integer type;
- **Maximum** constant, which has as a constant value 100.

Expressions and Operators

The concept of **expression**, in computational terms, is closely linked to the concept of mathematical expression, where a set of variables and numerical constants are related through arithmetic operators, composing a formula that, once evaluated, results in a value.

Expressions are an arrangement of **operators** and **operands**, whose value is assigned to each valid expression. Operands can be variables, constants, or values generated by functions. Operators identify the operations to be performed on the operands. Each data type has a set of related operators.

If several operands appear in an expression, the order of execution of the operations will be given according to some criteria:

- By explicit use of parentheses;
- In the order of precedence between operators;
- If there are operators of the same order of precedence, the evaluation is done from left to right.

Table 2: Examples of Operators and Their Categories.

Operators	Category
( )	Parentheses
No	Logical Operator
*** ** / div mod**	Multiplicative Operators
And Or	Logical Operators
= <> < > <= =>	Relational Operators

Arithmetic Expressions

Arithmetic operators are symbols that represent arithmetic operations, that is, the basic mathematical operations. These operators will be used to form arithmetic expressions (Table 3).

Table 3: Examples of Mathematical Operators.

Operator	Mathematical Operation
+	Sum
-	Subtraction
*	Multiplication
/	Division
%	Remainder of integer division

Note that the asterisk (*) character is adopted in most programming languages to represent multiplication. While the symbol (**) is adopted to represent the exponentiation operation.

Literal expressions

Literal expressions are those whose result is a literal value. This type of expression is much less frequent than the previous ones. Existing operator types vary from one programming language to another, with no standardization. However, a common literal operator is concatenate (+), where the first literal variable is joined with the second literal variable.

Ex:

"Gran" + "ito" ➔ "Granite"

"Feldspar" + " of" + " Ti" + " and" " Cs" ➔ "Feldspar of Ti and Cs" (Note the use of space before "of", "Ti" "and" and "Cs" with the to make a sentence clear and readable.

Logical expressions

Another concept used for expressions is logical expressions, whose evaluation result is a logical value (True or False). Mathematically, logical expressions are divided into propositions, which are affirmative statements or alphanumeric data that can be associated with a true or false value. Take the three most important principles of the propositions:

- **Identity Principle:** Everything is self-identifying. For example, the proposition p is equal to p (p = p), even if there is p = q;
- **Non-Contradiction Principle:** A proposition cannot be true and false at the same time. For example, given a proposition p it is either true or false, and never assumes both values at the same time;
- **Principle of the excluded middle:** Every proposition is either true or false, that is, there is always one of these cases, and never a third.

Based on this knowledge we will now evaluate the logical operators. Logical operators are known as **connectives** because they are used to form new propositions by joining two others. They are used to represent logical situations that cannot be represented by arithmetic operators (Table 4).

Table 4: Examples of logical operators.

Logical operator	Symbol
And	^
Or	v
No	~

There is a range of possible values resulting from operations performed with logical operators, as they can only assume T or F. The summary of these operations is what is called the **truth table** of the logical operators (Table 5). These results are products of different combinations produced by the interaction of the logical operators. In the case of operators, of course, we have that:

Table 5: Logic Operators Truth Table

P	Q	P ^ Q	P v Q	~P
T	T	T	T	F
T	F	F	T	F
F	V	F	T	T
F	F	F	F	T

We may need to compare two values or variables of the same type. For this, we will use **relational operators**, whose return of the relational expression indicates whether the comparison result was true or false (Table 6). For example, the expression 2 <3 is a logical expression whose value is true; in contrast, the expression 2 = 8 is a logical expression whose value is false.

Table 6: Relational Operators

Operator	Symbol
Equals to	=
Bigger than	>
Smaller than	<
Greater than or equal to	>=
Less than or equal to	<=
Different than	<> Or !=

As we enter the structures of selection, control and repetition we will return to this truth table concept to explain relational expressions and how they are theirs results.

CONCLUSION

In this issue, we have seen how data is sorted and how it is responsible for controlling the types of variables. We have seen that variable names have specific rules for their use. We also started the concept of expressions, both logical and numerical, to begin our approach to the next edition: building a program in Pseudocode.

Proposed Exercises - Answers on SEG Student Chapter Geophysical Society website - Taken from (1) and (2)

Classify the data specified below according to their type, indicating with I the integer data, R real, L literal, B logical (Boolean), and N for which it cannot be defined at first.

( ) 0.21	( ) T	( ) “0.”	( ) 1
( ) 1%	( ) “John”	( ) 0,35	( ) +36
( ) .F.	( ) -0.001	( ) .T.	( ) C
( ) +3257	( ) “abc”	( ) “-0.0”	( ) F
( ) “+3257”	( ) +3257.	( ) Mary	( ) “a”
( ) “.F.”	( ) ± 3	( ) .T.	( ) .T

2) Mark with C the correct identifiers and with I the incorrect ones. Explain what is wrong with the incorrect identifiers.

( ) value	( ) _b248	( ) student*grade
( ) a1b2c3	( ) 3 x 4	( ) Mary
( ) km/h	( ) xyz	( ) company name
( ) room_215	( ) “grade”	( ) ah!

3) Assuming that the variables SG, SN, RNUM, and GD are used to store the student grade, student name, registration number, and gender, declare them correctly by associating the appropriate type with the data to be stored.

Note the following variable declarations and their respective assignments and answer the questions below:

var integer NUM1 = 10;

var integer NUM2 = 5;

var integer NUM3 = 200;

var integer NUM4 = 200;

4) Write T or F in the expressions below :

Exemple: (F) NUM4 > NUM3;

a) ( ) NUM1 > NUM2;

b) ( ) NUM1 < NUM3;

c) ( ) NUM1 < NUM4;

d) ( ) NUM3 = NUM4;

5) Write T or F in the expressions below :

Exemple: (F) NUM1-NUM2 < NUM2;

a) ( ) NUM1 + NUM2 > NUM3;

b) ( ) NUM1 * NUM2 < NUM4;

c) ( ) NUM3 – NUM4 != NUM4;

d) ( ) NUM3 / NUM1 < NUM4;

6) Write T or F in the expressions below :

Exemple: (F) NUM1+ NUM2 > 10 e NUM3 - NUM4 = NUM3;

a) ( ) NUM1 / NUM2 > 0 e NUM1 + NUM3 > NUM4;

b) ( ) NUM1 * NUM2 > 40 e NUM3 - NUM1 > NUM4;

c) ( ) NUM1 - NUM2 = 10 e NUM2 + NUM3 > NUM4;

d) ( ) NUM1 + NUM2 < 10 e NUM3 - NUM4 = NUM1;

REFERENCES

(1) Apostila de algoritmo e lógica da programação – Algoritmos – Parte 1 – Departamento de Computação e Automação. Centro de Tecnologia. UFRN / UFRN, 2004.

(2) Carvalho, Victorio Albani de. Lógica de programação / Victorio Albani de Carvalho. – Colatina: CEAD / Ifes, 2009.

Ferrari, Fabricio; Cechinel, Cristian. Introdução a Algoritmos e Programação. Versão 2.2.

Student Chapter website:

segchapteruerj.wixsite.com/geophysicalsociety