# The Role of GIS in Finding New Caves

*Following his description of how multiple geophysical methods are being used to find new caves, **Atanas Rusev** discusses the use of geographical information systems in cave exploration.*

Science and technology can be used successfully to find new, unexplored caves. Combining different geophysical methods can provide valuable information for the location of new caves, as I presented previously (Rusev & Slavova, 2018). However, obtaining and analyzing standalone data is often not enough to get the whole context to explore a huge cave system or limestone area.

Here we present a practical complete workflow from obtaining data, plus its storage and analysis using GIS (Geographic Information Systems). Advanced GIS systems have a vast spectrum of tools for analyzing large data collections of different forms of geodata.

Furthermore, mobile GIS applications can provide access to all this data in the field and every exploration party can take advantage from it.

## Obtaining Data

The first and probably most important part of every exploration is to obtain valuable data. Data is collected in terms of its further use and often in cave explorations, collected data is very limited and describes only narrow qualities of karst features. As an example, getting only the 2D

data of a traditional cave survey is no comparison to getting 3D data. The latter allows further analysis in the context of relief, satellite or even geological and other special maps or data of the same area. So, the most important first step is to get quality data that can be used in a wide range of applications and analyses.

Our practice is to use several data collectors, specifically surface location data obtained in the field, and GNSS (e.g. GPS) receivers as described below.

As technology has grown, mobile phones have sensors that obtain a location from GPS, GLONASS and BeiDou or other networks, and their accuracy is enough to spot some karst objects.

However, for precise location of karst features we use mainly GNSS receivers with high accuracy (Trimble, CHC), as often an accuracy of 10-500mm horizontally and vertically is more than adequate for discrete objects varying in size from 100-500mm to a few metres, for example cave entrances, sinkholes, etc. We also prefer to use these devices because they achieve better results in forest or mountain areas with poor navigation satellite visibility. Their ability to further carry out online/offline coordinate correction is also a plus.

Surface-specific data includes the following. Thermal data is obtained mainly using FLIR cameras and sensors ('Ex' series, Flir One Pro). GPR data is obtained using MALA georadars with a GNSS receiver. Magnetic field data is collected with a GSM-19 gradiometer and GNSS receiver. Other sources of data include gravity and resistivity measurements.

Remote surface data is obtained from orthophotos. Multi-spectral imagery or LIDAR data is often valuable in finding new cave entrances.

Underground data collection involves the use of cave surveying tools (Trimble LaserAce, DistoX2, total stations, 3D laser scanners (Trimble, CHC, etc.)

## Storing Data

The next step is to store obtained data on karst features in a GIS, and the most important step beforehand is to make proper structure containers for this data, often structured in file geodatabases, raster datasets, etc.
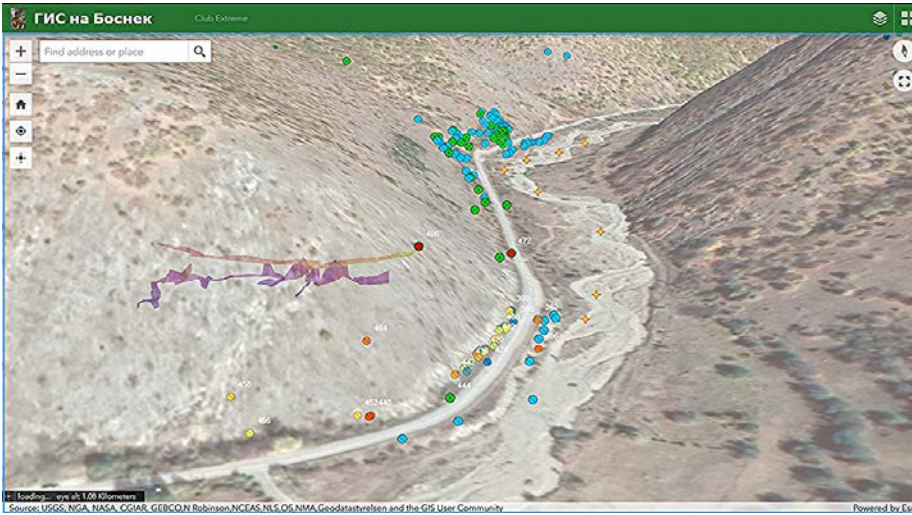
## Inputting Data to GIS

Data can be imported into the GIS either offline or online. With the old offline method, data is saved locally on
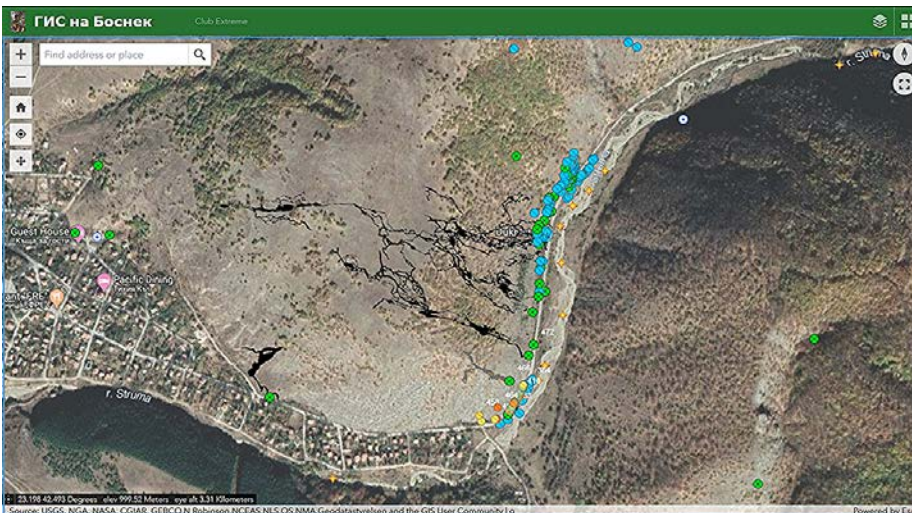


*Trimble GNSS at New Cave Entrance*
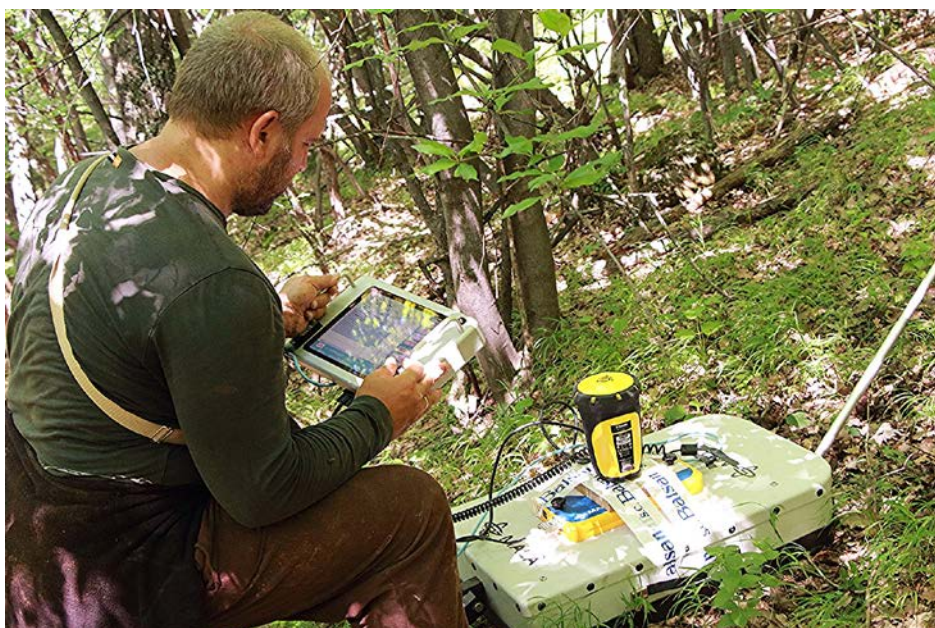


*Collecting GPR and GNSS Data in the Field*

*Pepeliankata Cave in 3D with Karst Features in Bosnek CaveGIS*



*The Longest Cave System in Bulgaria, Duhlata (18km) with Karst Features, Dig Entrances, Cave Entrances, Springs and Sinkholes in Bosnek CaveGIS*

some device, during collection in the field, and is later imported into the GIS structure.

With the online or real-time method, GIS server technology is used. Now, all collected data in the field is transferred in real-time into the GIS structure. Software products used for this are ArcGIS Collector, Survey123 for ArcGIS, ArcPad, ArcGIS for Mobile, and our custom Web/Android/iOS apps. Once on the server, the data can be served in real-time via mobile applications. This benefits other explorers who are in the field at the same time, for example, those looking for new cave entrances with thermal cameras over a wide area. One of the advantages of this method is data security and reliability.

## Applying GIS Underground

Once the data is stored in a GIS structure, the next step is to organise it in a content-aware fashion for further analysis and use. We mainly use commercial software of the ESRI family of

products, namely ArcGIS Desktop, ArcGIS Pro and ArcGIS Enterprise. It is worth mentioning that open-source GIS software can also be used but, in our experience, there can be several limitations concerning workflows, protocols, representation and analysis, especially in the client-server communication part.

Our practical approach to using GIS in our exploration dates back to 2006, with the collection of karst features geodata in the Bosnek karst area in Bulgaria. Here we present several successive GIS workflows and the online GIS systems produced, which helped us a lot in our expeditions.

## Case Studies
### Bosnek CaveGIS

Duhlata, Bulgaria's longest cave (18km) is located in the Bosnek karst area. The potential is for that cave to grow to 30-35km in length. However, more interesting is the presence of still unexplored giant cave systems several kilometres north of Duhlata. Extreme-

Vreloto (currently 10km), has the potential to reach 70-80km in length, an aim that we've pursued for the last 35 years.

As the collected data has grown every month for all these years, using GIS was the only possible way to organize all the data in proper fashion for further use.

Data in GIS is grouped in layers and sublayers. In the Bosnek CaveGIS, we have several layers, e.g. Surface Karst Features Layer (cave entrances, dig entrances, sinkholes, traced underground rivers, etc.), Underground Karst Features Layer (cave maps, explored underground rivers, etc), Science Layer (GPR data, magnetometer data, thermal explorations, biological layer, archeological layer, etc), Satellite and Orthophotos Layer, Geological Maps Layer, Topo Maps Layer (1:5000, 1:10000, 1:25000 topo maps). Every single sub-layer and feature in the GIS comes with the organized attribute data, which can be queried and analyzed in the context of all the layers. The real plus of using a GIS is the possibility of complex analysis of many karst features across a number of other layers and features. Also, the same GIS system has been developed and used for the Ponor karst area in Bulgaria since 2012.

A fresh showcase example of using our Bosnek CaveGIS is an exploration hike. We navigated with our mobile GIS app near the main fault on the geological map of the karst area and used a thermal FLIR camera on a -20°C cold morning on January 8th, 2019. As a result, we discovered a prospective new cave entrance. To date, we've been able to penetrate about 200m and we are still going. Furthermore, another five entrances were located with the thermal camera over the next few days and, by using GPR afterwards, we chose the best entry points. We then made a detailed 3D map of the new cave. Now, within the context of relief, satellite and geological map data, we have got a good idea in which direction we should go in the near-surface collapse in the cave.

## Mexico CaveGIS Project

Mexico is probably one of the most spectacular karst areas in the world. It has hundreds of kilometres of underwater caves (Sac Actun 362km, Ox Bel Ha 271km, K'oox Baal 94km) and huge volumes of data has been acquired during the last few decades.

In 2014, an idea was born to summarize data from Riviera Maya cave explorations in a GIS system, similar to Bosnek GIS. As many of the exploration

parties work mostly in isolation, it was difficult to obtain reliable sources of data. However, explorer Peter Sprouse was very welcoming and open. He was supportive of the idea and provided his database of cave entrances for the project. Several other exploration parties joined and provided information from their projects. As cave politics in that area is rather stranger than normal, this project was not presented to the wide exploration public there and was probably intentionally ruined in 2017. In 2019 we started it again with recent satellite, relief and cave maps, and other valuable data, including new 3D representations to help exploration parties in their activities.

The Mexico CaveGIS contains several layers and sublayers: Mexico Cave Entrances (Peter Sprouse), Peter Sprouse Cave maps, Sac Actun, K'oox Baal cave system (with permission from the explorers), different Exploration Team layers, Cave maps from C-share site (old), lidar DSM data, lidar DTM data, lidar Hillshades, SRTM relief data, ASTER DEM data, satellite backgrounds (Google, DigitalGlobe), ESRI, etc., and local drone orthophoto layers.

It is worth mentioning that there is publicly available high resolution 5m lidar data for parts of the area. This shows hundreds of still unexplored cenotes which are clearly visible and detectable.

With the help of the Mexico CaveGIS, system explorers can easily connect huge underwater caves. Alternatively, in combination with Lidar relief data, collapses can be viewed. In this area, this means either new cave entrances, cenotes, or the end of development of the underwater system, although it is also possible that the underwater cave goes around the collapse and continues.

One of the most valuable parts of the mobile GIS app is the ability to navigate in the jungle with all available GIS data on-screen.

As online communication is preferable, it is possible to use wide-area local internet network across the jungle with simple and cheap wi-fi devices, which can cover 50km or more across this relative flat landscape. This can further help obtain precise coordinate locations with GNSS receivers, mapping and navigation. Offline navigation and GIS use is also possible.

## GIS Technology in Practice

GIS technology is perfect for specialists but, in practice, it needs to be
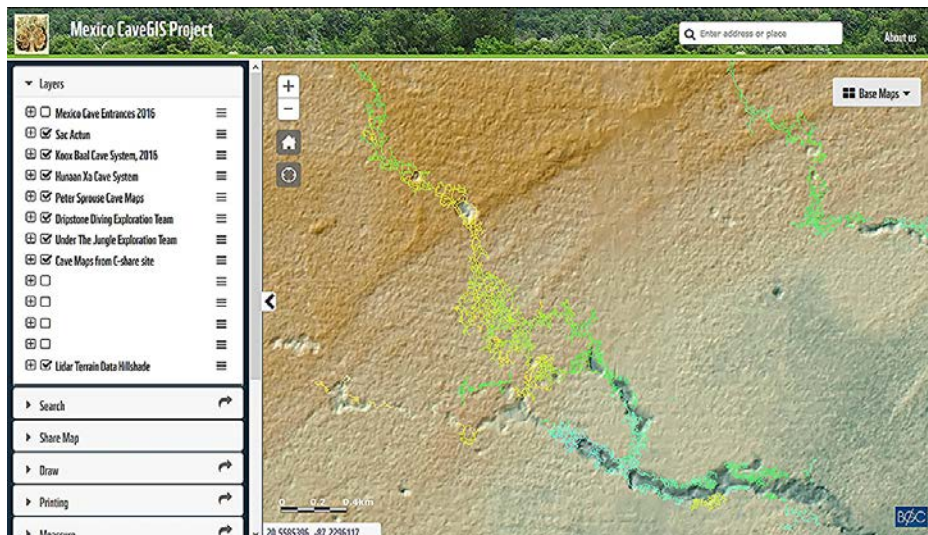


*Lidar Data, Cave Data (Peter Sprouse) and Possible New Cave Entrances (Cenotes) in Yucatan, Mexico*



*The Sac Actun Cave System in the Mexico CaveGIS*

simplified for wider use. This implies the use of a GIS server, the role of which is to provide huge amounts of GIS data to clients. In our case, the client is a mobile or desktop GIS application. This provides all the parts of the GIS system that we are interested in, for analysis in a web browser or application window, which is available and understandable to any cave explorer.

Mobile GIS applications are very handy for field explorations as you can navigate, collect data and have access to all of the huge GIS data collection. Analysis of GIS data is also possible on the spot, as the mobile app is open for development of custom geo tools. It works on any Android or iOS mobile phone.

## Future of GIS

As exploration of big cave systems and wide karst areas often means the analysis of huge volumes of data, the only possible

solution is via a GIS system. An example is the cave rescue operation in Thailand last year. Many of the GIS approaches and software mentioned in this article helped with the rescue plan and actions.

The latest developments in GIS software allows data to be fully presented in 3D within the mobile app. Since the underground and surface are 3D environments, this is a great advantage. We have now transferred all our CaveGIS systems to a 3D environment, which will be open to every explorer to analyze.

GIS is a nice example of how technology and science contribute to cave exploration. And don't worry – the hard digging job at a new cave entrance still remains.

## Reference

Rusev, Atanas & Slavova, Tanya (2018) *Practical Geophysical Methods of Cave Detection*, CREGJ **103**, pp. 18-21.