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Zapp: learning about the distant landscape

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Zapp: Learning about the Distant Landscape

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ABSTRACT

A successful application area of mobile technology for learning has been to provide location-based guides that inform students or tourists about their immediate surroundings. In this paper we extend this location-based learning to the distant landscape, so that a visitor to an unfamiliar area can ask "what can I see over there?", or can annotate the landscape by taking photos of distant features and adding text or audio notes that are the automatically located as points on a digital map. We describe a system, named Zapp, for learning about the distant landscape. It uses a line of sight algorithm computed over a digital surface model stored on a smartphone to determine which distant feature is showing in the centre of the smartphone camera screen. In 'query' mode the system can inform the user about pre-stored elements of a landscape such as names of rock formations. In 'capture' mode the user can store a note about a distant feature, linked to a photo and to its map coordinates. A trial of the system with university students has demonstrated its usability and usefulness in interpreting the geology of a rural landscape.

BACKGROUND

Finding out about one's immediate environment is a well-recognised application of mobile learning. This can be achieved through the use of a handheld device with location sensing technology, such as GPS or phone cell positioning, running an application to deliver information in text, audio or multiple media about the user's current location. Examples of such outdoor mobile guides include Cyberguide (Abowd et al., 1996), GUIDE (Cheverst, et al., 2000) and Caerus (Naismith, Sharples & Ting, 2005). See Kray, Baus and Cheverst (2005) for a survey of location-based guides. While there can be problems with accurate positioning, particularly in an urban environment with areas of 'GPS shadow', location-based guides have provided a foundation for research and development in contextual mobile learning. Several research prototypes (e.g. Quinn & Cartwright, 2009; Bradley et al., 2010) have been based on the Mscape platform (Stenton et al., 2007) produced by HP Labs in Bristol to develop mobile media guides and games.

Another approach is to augment the natural landscape with instructional information and stimuli for inquiry learning. The best-known is Ambient Wood (Rogers et al., 2004) where information and instruments were embedded in a woodland for children to carry out investigations into its biological processes.

All these examples assume that the learners are gaining information about their immediate surroundings. But what if they want to learn about a distant object, landmark, or area in the landscape? Some examples of such need include the following: tourists interested in information about visible landmarks such as the names of distant mountain peaks; students on a geology field trip learning about rock formations in the surrounding landscape; visitors to a heritage site exploring how an area looked in historic times; or for general users of camera phones, being able to log one's photographs of distant landscape features on a map to show both the photographer's position and the location of the distant feature.

Current technologies can offer some assistance by two different methods: augmented reality based on device position, orientation and tilt; and image recognition of landmarks. Augmented reality systems such as Layar (http://www.layar.com/) and Wikitude (http://www.wikitude.com/) show information about nearby buildings or landmarks overlaid on the phone camera screen. The problem is that these applications only show what is in the general direction of the camera, not what the user can actually see. If the user's line of sight to a target building or landmark is blocked by another building or object, then this can cause confusion or misinformation. The other approach (with Google Goggles being most widely used example, http://www.google.com/mobile/goggles) uses image recognition software to identify a landmark within a photo taken by the phone camera and then search for relevant information about it. For

instance, using Google Goggles to capture an image of the Golden Gate Bridge in San Francisco might return Google search entries for 'Golden Gate Bridge' alongside its position on Google Maps. This works well for famous landmarks that fill the viewfinder, but cannot recognize less well-featured parts of a landscape, or landmarks at a distance.

A more widely useful tool for learning about the distant landscape would be a 'tell what I see' application that enables a user to point a phone camera at a landscape feature and see or hear information about what is showing on the screen. Additionally, a 'mark what I see' application would locate on a map what is shown at the centre of the camera viewfinder, and then allow the user to add information such as a text label or audio description. This is the design aim for the Zapp application.

ZAPP APPLICATION

Figure 1 shows the current user experience of Zapp, in use at the Lake District National Park in the North West of England. The system has two modes, each of which involves just a single button press. In 'query' mode, the user moves the camera display screen of an Android phone running the Zapp application until the central cross hairs turn from red to green, and a descriptive text label appears, showing it has detected a known landmark. The user then presses the 'What is this?' button and the screen gives a previously prepared multimedia presentation about that landmark. In 'capture' mode, the user points the centre of the screen at a distant location, presses the 'Capture' button where the coordinates of the distant location are logged as well as a photograph. The system associates that photograph with the location, so that it may be used later for authoring tours, or as part of a response to a query.

Figure 1. Screen display of the Zapp application, showing it recognizing St Herbert's Island in Derwent Water

Belying the simple user interface is a complex combination of hardware and software. The entire application must run on the mobile device, since a reliable internet connection cannot be assumed for an outdoor rural location. The device stores a digital surface model (DSM) of the terrain where the application is being used, which might be a city with buildings, or a rural landscape with hills and valleys. The DSM can be provided by airborne laser scanning (Light Detection And Ranging - LiDAR) or as in the case of the Lake District model airborne radar. This matrix of elevation values can be regarded as a 'Lego block' representation of the terrain (see Figure 2). For the Zapp Lake District demonstrator, each block represents a 20m by 20m square on the ground (20m resolution), producing an array size of 490,000 cells for the 15km by 15km study area, which can be stored in memory on the mobile device. For more complex terrains (e.g. cityscapes) LiDAR data of higher resolution (2m or finer) covering a smaller area could be used, here the DSM represents the surface 'canopy' of trees, buildings and other prominent objects on the ground surface.
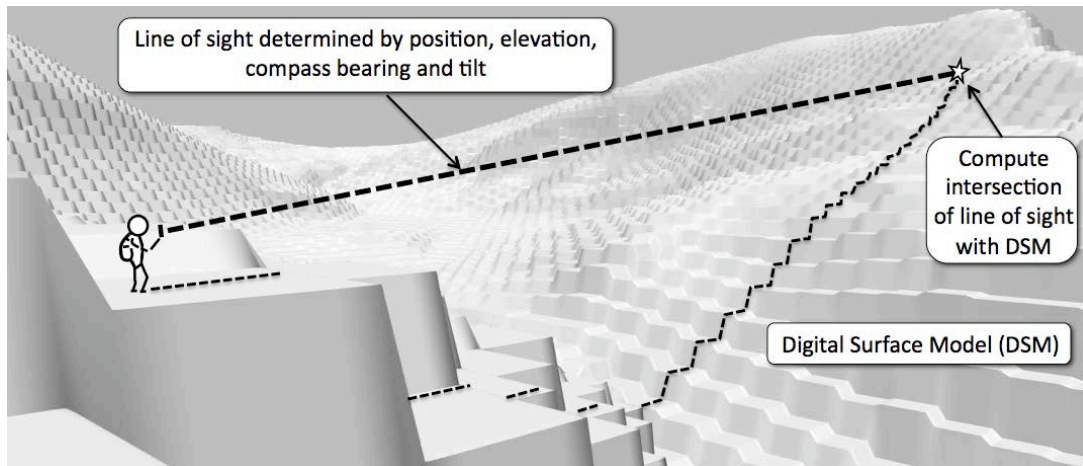
Figure 2. Schematic of computation for the Zapp application

The Zapp application combines this DSM with data from the mobile phone indicating the device's current location (computed from GPS data provided by the device), compass bearing (from the device's inbuilt compass) and tilt (from its tilt sensor). The application then computes the line of sight (LOS) to the distant location using the following method (see also Figure 2[1]):

1. Compute the height of the device, using the GPS data mapped to the surface model (raised by 2m to represent the approximate height of the camera above ground)
2. Using the position, orientation and tilt data, compute a line of sight from the device over the DSM. This is done by iteratively calculating both the height of the line of sight and the height of the DSM cell in the direction the device is pointing, such that:
   a. if the calculated height of the DSM cell is less than the height of the line of sight then go to the next cell, or
   b. if the height of the DSM cell is greater than the height of the line of sight, then this is where the sight line intersects with the terrain, so record its map coordinates as the target location.

Once the map coordinates for the target have been computed, then Zapp opens an interface to play the associated media (in display mode) or record an annotation linked to that map location (in capture mode).

ACCURACY IN THE FIELD

A controlled study was undertaken to test the accuracy of the Zapp system. In brief, the application was tested in the Northern Lake District, in the area to the West of Derwent Water shown in Figure 1. Three researchers walked along a predetermined route and approximately every 100 meters they stopped and captured three salient landscape features, agreed amongst the researchers, of differing sizes and distances using Zapp in 'capture' mode.

In total 468 capture attempts were made, for 22 different landscape targets at 12 locations along the route. Of these, 385 were successfully captured and 83 were missed, with the line of sight being recorded as above the highest point (in Figure 2, for example, it would be recorded as 'missed' if the line of sight was computed as being above the top of the distant mountain). For those points successfully captured, the mean error was calculated for three different types of landscape object: hilltop peaks, defined points, and undefined points. Defined points were easily recognizable features of the landscape, such as the gable end of a specific house. Undefined points were more ambiguous regions of the landscape, such as the centre of St Herbert's Island.

Since the output from the Zapp system in capture mode is the map reference of the captured landscape feature, the location of each attempt can be compared to the actual map location of the landscape feature, to measure the distance error. For example, if a user attempts to log the location of a house in 'capture' mode, the error is calculated as the linear distance between the logged point, as computed by the LOS algorithm, and the actual position of the house on a map. The results showed that defined points were the most accurate, with, for example, the mean distance of the computed location from the actual map reference being 375 meters at a range of 1-2 kilometers. The greatest mean errors were in the location of undefined features and distant mountain peaks. Overall, there was a wide variation in accuracy.

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[1] Note that Figure 2 is not to scale, in that each DSM cell is much larger (20m width) than the user.

Some reasons for the errors include: camera wobble when the user is capturing a point with the handheld device; seeing a flat mountain top from a low angle so the perceived peak appears closer than the actual peak; and an artifact of the 'Lego block' DSM where the edge of a nearby terrain element falsely obscures the computed line of sight. Each of these could be addressed in different ways: by resting the camera on a tripod or surface or capturing multiple points; by having a 'snap to fit' to the nearest salient map feature; and by the algorithm ignoring the 'blocking effect' of nearby DSM cells in the terrain model. These improvements will be explored in future versions of Zapp.

The field testing helped to define the level of accuracy that was currently possible with Zapp in terms of the size of features of interest that could be queried. This knowledge helped to shape a field exercise designed to explore the use of Zapp to support undergraduate students of Geography in learning about the formation of the physical landscape in the Lake District.

FIELD TRIAL OF THE ZAPP SYSTEM

One aspect of Geography fieldwork in an area such as the Lake District is to foster an understanding of how various factors have shaped the landscape students can see around them. This includes the influence of sub-surface geology on the shape and texture of landforms at a range of scales. The skills associated with learning about such relationships include the ability to interpret geology maps and relate them to the three dimensional landscape. As with many aspects of geography fieldwork this requires careful observation of the landscape at a range of distances from the observer. The process of in-field interpretation may on occasions be supported by a knowledgeable human field guide, but sometimes students working independently or in small groups may not have the opportunity to get on-demand expert confirmation of their observations. On previous field exercises to this area, the students were given paper sheets with 3D views showing geology maps draped over a digital model, as illustrated in Figure 3, however these related to only a few key stopping points for which panoramas were pre-generated. An exercise was therefore developed therefore to test the use of Zapp for the query of distant landscape features, in this case areas of ground underlain by various types of rock and sediment.

Figure 3. Geology draped over a digital model as used in previous field exercises

Features of interest authored for use by Zapp can be assigned any size or shape of area on the map. The earlier field testing had suggested that at distances of one to five kilometers the application was not sufficiently accurate to inform about features smaller than approximately 200 metres in width. In the case of geology there is continuous map coverage of rock and sediment types for the area, at a range of scales and levels of classification, so we had the opportunity to create sets of zones that were large enough to be usable by Zapp.

Digital geological data created by the British Geological Survey was processed in the Geographical Information System (GIS) ArcGIS, reclassifying sets of digital aerial feature (polygons) for both solid rock geology and surface deposits to produce a combined map showing the dominant surface rock or sediment type for broad areas of the landscape. For use in Zapp this was converted to an array of values representing geology type, such that any distant location queried by the application would produce a mixed-media description of that rock or sediment type. In this case, areas adjoined each other forming a contiguous coverage, with many areas sharing the same geology type. For other applications of Zapp (such as describing specific landmarks) there could be separate areas of interest each with its own unique properties relating to a particular location. Figure 4 shows the geology zones used for this exercise along with an example of the teaching material for one zone. Whilst Zapp had the ability to serve audio and video, for the purposes of this exercise the style of media used for all zones was consistent, being a combination of summary text and image.
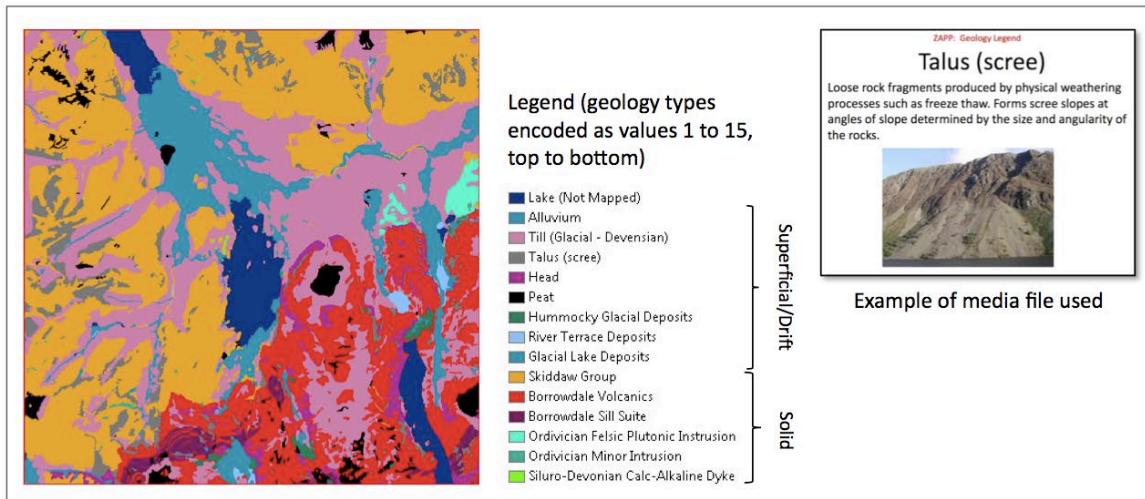
Figure 4. Geology zones and example teaching content for the Zapp application

The exercise was part of a three-day residential Geography field trip for first year undergraduate students, forming one of several optional day projects, with 19 students choosing to take part. The main learning objective was to account for the physical landscape around the study area shown in Figure 4. This area has undergone periods of geological uplifts which have created the differences in topography and periods of glaciations, carving out the landscape and producing its iconic views. More recently, parts of the landscape in the area of study have experienced human intervention in the form of visually salient pasture land and wood plantation. Geologically, one of the reasons the study area is suited to this kind of student inquiry is its wide variety of rock types within a small geographic region. The Borrowdale volcanics are a set of rock types characterised by their ruggedness and resistance to weathering, shown in Figure 4; the Skiddaw Slates are softer rocks, more weathered and therefore less rugged. Features associated with these rock types can be seen in the landscape with various levels of visibility. The students were asked to gather evidence from the landscape in order to produce a geological story of the landscape with observed examples.

The 19 students were split into three groups of roughly equal numbers for each of the two runs of the project. They were given time in the field centre prior to their field work to prepare for the trip, using provided materials to understand a little about the geological history of the area and to get used to using Zapp around the field centre which was conveniently located within the study area. In addition to Zapp, the students were provided with paper geology maps of the area, cameras to produce still and video logs of their learning activities, and field workbooks for sketches and notes. After their preparation, the students were taken to the bottom of Catbells Fell, as when climbed it offers views of varied rock types. Whilst in the field, the students were encouraged to use Zapp to capture a large set of data points of features in the landscape which provide evidence for the geological history of the area, to be analysed later at the field centre and organized into a story. Over the two runs of the project the students captured a total of 293 points using Zapp (Figure 5).
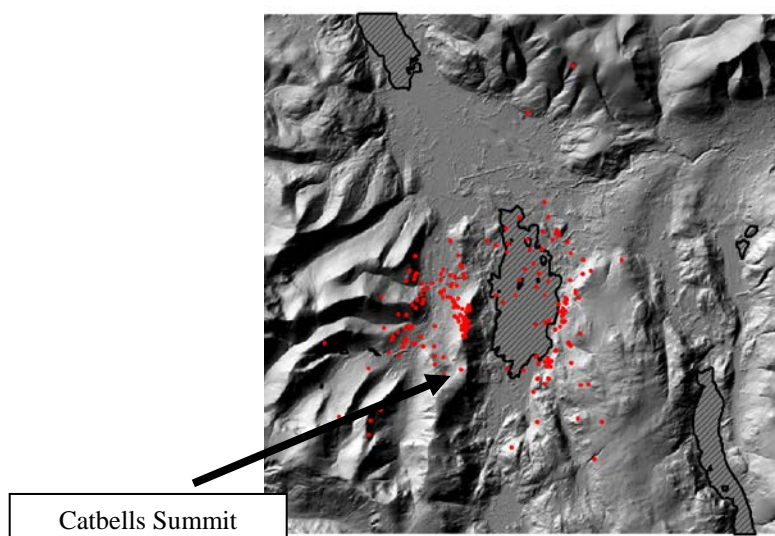
Figure 5. Points captured with Zapp by the student groups, bodies of water shown in crosshatching

ZAPP AS A FEATURE RECOGNITION AID

During the geography field trip, the students used Zapp as both a data logging mechanism and a querying tool. With the application in 'query' mode, the students were able to point the screen at any part of the landscape in view and press the 'What is this?' button. Then, the application displayed information about the underlying geology of the landscape in the form of a standardized slide which contained an image and some peripheral information about the piece of landscape they were viewing.

As the students were being assessed on their production of a media rich PowerPoint presentation, they also used Zapp to collect examples of geological features in the landscape. To do this, the students switched the application to 'capture' mode using a standard menu option. In this mode, the crosshairs on the screen are blue and do not change colour when sweeping over a point of interest. When the user sees a POI they wish to capture, they align the crosshairs with that POI and press the 'Capture' button. Zapp then activates the LOS algorithm to log the coordinates of the POI and simultaneously stores the image on the screen as a photograph. The coordinates of the POI, the device location, its compass bearing and its tilt are all logged to a text file stored on the device. The POIs can be plotted later on a digital map and a numbering system within the file allows for easy lookup between the photographs and the logged data.

After the students finished their time in the field they could access both the photographs and the log data at the field centre. They then used some of the data from Zapp to construct their media rich PowerPoint presentations for assessment. Several groups also plotted the points they had captured on a 3D model of the landscape, to further explain their findings.

The researchers gained information about student use of the Zapp application from direct observation of the students, from viewing the video recordings made by the students as logs of their learning activity, from the data points and images captured by the student groups, and from items in their assessed presentations that reported their impressions of the Zapp application. Due to the students' prior knowledge of physical geography and their time in preparation, they had grounding in the kinds of features they would be looking for in the landscape. When Zapp was being used in 'query' mode as a feature recognition aid, the students tended to identify something in the landscape which could be a feature of interest, then point the Zapp screen at the feature to see if the result tallied with their expectations. This checking activity generally occurred for very large features, such as a range of Borrowdale volcanic rocks.

Student 1: "So, this should be Borrowdale volcanics along here and that's sill up there (pointing at Zapp). Hopefully, fingers crossed."

S2: "Beautiful specimen of Borrowdale volcanics coming up here."

S1: "They're just so craggy in comparison to the Skiddaw group found over here."

Zapp was also used by the students as a tool for sweeping the landscape in order to explore what could be seen. As the students were assessed on their production of a rich media PowerPoint presentation, much of their videotaped use of Zapp was posed with a view to including the clip in a presentation later on. Several of the groups over both days stood on top of Catbells and recorded a 360° panorama of the area. This appeared to give the students a method of orienting themselves by what they could see. Additionally, whilst performing these sweeps of the area, some groups found that they would discover features in the landscape which they were unaware of, usually because of lack of feature salience. For example, one group found a peat deposit on the Borrowdale volcanics which was quite small and because of the oblique angle at which it was situated they found it difficult to get a reliable lock on the deposit. But by using Zapp in this way, through group discussion they were able to hypothesize where it might be;

S1: "There's some peat over there as well as some talus"

S2: "But due to some of the limitations of the device, we can no longer identify the peat"

As a part of their assessment, the students were asked to present on a slide what they thought of Zapp as a tool for learning in the field and were encouraged to include any suggestions they had to improve its usability. The student's responses indicated that they liked the simple interface and the quick response of the application which was partly due to the data and calculations all being completed on the device without having to connect it to the internet. The students also used the 'capture' mode of Zapp as part of their data collection exercise, to identify features that contributed to their exploration of the landscape geology.

DESIGN CONSIDERATIONS AND IMPROVEMENTS TO ZAPP

Some changes were subsequently made to the user interface as a result of the feedback provided by the students, both as part of their assessment and from the video they had captured in the field. Although the learning objective was to understand the physical landscape, not to evaluate a technological intervention, the students were made aware that the system may not record an accurate position for a captured POI and that the DSM underpinning Zapp did not match the real world perfectly. From this, the main suggestion made from their assessment and infield feedback was that the user

needed to know roughly the position of the point the device was calculating. This was particularly apparent when the POI they were trying to capture or query was at an oblique angle (figure 6) as error in the sensor input to the LOS algorithm could mean that the device captures or queries an unintended point. Also, due to the small screen size of the device and a lack of a zoom function, it was sometimes difficult to locate a potential POI on the screen.
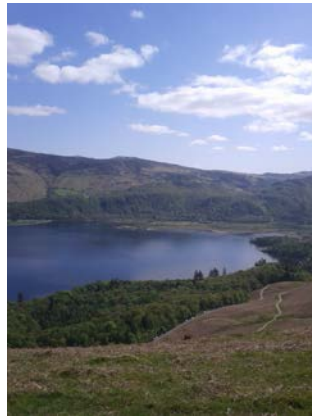

Figure 6. Photo captured from Zapp with an ambiguous POI

The simplest method of providing feedback to the user of what the device was pointing at in the landscape was to make the screen crosshair dynamic, such that the space in the centre of the crosshairs closed when the Zapp algorithm was detecting features of interest far away and opened out when the detected features were close. With this implemented, the user is now able to trace the crosshair across the landscape until the size of the central region of the crosshairs corresponds to the user's estimate of the distance of the POI, therefore increasing confidence to the user that the system has locked onto the correct point in the landscape.

Another suggestion which was implemented was to merge some features of the query and capture model such that the name of the POI being looked at would appear on the screen in capture mode and also be recorded in the captured points file as part of the logged data. This was suggested because of frustration when identifying a feature in the landscape in query mode and then having to re-find it in capture mode (without the text on the screen naming the current POI). Originally, this was not implemented to discourage students from "treasure hunting" in the landscape to attempt to find all of the media.

Future work will include more detailed testing of components of the system, such as the effect on error of changing the resolution of the DSM, and undertaking comparative studies of how Zapp enables learning in the field.

CONCLUSIONS
Students of geography, environmental sciences and history all have an interest in understanding the visible landscape, as do tourists at heritage sites and visitors to unfamiliar cities. For students, a central challenge is to enable learning in the field, so that they build an understanding of the landscape through a promotive cycle of visual scanning, identification of salient features, immediate confirmation of their visual interpretation, leading to their further scanning of the landscape for more subtle cues. Their learning can also be assisted by a 'landscape annotation' facility where they can record textual and audio notes linked to captured camera images of visible features that are then referenced to map coordinates. Later, they can access these notes when looking at the same feature from a different location and perspective, or they can study their collected pictures and notes located on a digital map to 'tell a story' about the rural or urban landscape. For tourists and visitors, there is an opportunity to provide a richer experience than current technologies that inform only about their current location or major landmarks, enabling visitors to scan their visual surroundings and ask, for example, "what is the name of that mountain peak?" or "what building can I see in the distance?". In this paper we have described a general purpose solution, based on a line of sight algorithm computed over a digital surface model stored on a smartphone. The algorithm and DSM can be adapted to open rural landscapes with coarse-grain mapping based on radar data, or more restricted urban environments with high resolution LiDAR mapping. Errors arising from inaccuracies in the smartphone compass and tilt sensors and granularity of the DSM will be reduced with next generation smartphones containing more accurate sensors and larger memory. A field trial of the Zapp system with Geography students has shown that the system is usable and useful and more useful than previous paper-based methods for gaining a full understanding of surrounding rock formations, to create a narrative explanation of the regional geology.

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