Communication in geology: a personal perspective and lessons from volcanic, mining, exploration, geotechnical, police and geoforensic investigations

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Communication in geology: a personal perspective and lessons from volcanic, mining, exploration, geotechnical, police and geoforensic investigations

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Abstract: Geologists are frequently required to convey the results, advice and recommendations from geological investigations to a variety of end users. Often, it is the communication of the information that is the most challenging and can be more difficult than the investigation itself. Most of these investigations use highly sophisticated scientific techniques and geological terminology. When combined with cultural and language barriers, and social, political, religious or economic constraints, this makes it difficult to convey the correct message, and for the recipient to understand the implications of the geological information. The failure to effectively and accurately communicate this message may reduce the usefulness of the information being provided. Communication must be considered part of a geological investigation because if the correct message is not conveyed properly, or is misunderstood, the consequences can be catastrophic. Communication is an ability that professional geologists must have to interact successfully with colleagues, other professionals and the public. It is a skill learnt by training and experience. Spoken communication relies on interpersonal skills and the ability to convey information effectively, confidently and consistently. This paper provides case studies and draws upon the experiences of the author.

For almost two decades, the author has participated in several geological projects around the world. These projects have included the monitoring and prediction of geological hazards (e.g. volcanoes and landslides), mining hazards (e.g. subsidence, fault reactivation, fissures and mine gas emissions), geotechnical ground investigations, mineral exploration, and the provision of geological expertise to support police searches and forensic investigations. Although many of these projects have been technically challenging, requiring geological judgements to be made, often with incomplete data and information, it is the communication of complex geological information that has been, and remains, the most challenging.

The results, advice and recommendations from geological investigations are subsequently conveyed to end users, clients, policy-makers, the public or the media. The recipient of this information may be other technical specialists or non-technical people, or both. Typical recipients of geological information range from schoolchildren to specialists in their respective fields.

Geologists have not been (conventionally) trained in the skills of communication, so how do geologists convey the complex technical geological information to the decision- or policy-makers, and how do they overcome the physical, cultural, political, social, religious and interpersonal constraints that exist in different parts of the world during communication? The principal objectives of this paper are to raise awareness of the importance of communication, to outline some of the problems in communication, and to see how these have been overcome. It highlights some of the more basic fundamentals of communication, and it draws primarily on the experiences of the author with particular reference to communicating in sensitive and high-profile investigations.

Communication and geology

Communication may be considered the process by which geological information is conveyed (by a geologist) to another person, by means of verbal and non-verbal methods. This may also be considered as the sharing or exchange of geological knowledge. From the geologist's perspective, geological information is required to make the correct decision or judgement about 'the ground', or to assess the consequences and risks associated with a particular geohazard. The recipient requires the information to make decisions that could, for example, influence engineering design, determine the location of structures, roads and utilities, or could help to locate mineral resources, to find a grave, or to help save lives. Communication therefore consists of both the giving and receiving of information.

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Professional geologists use technical language and this is as necessary as vocabulary when learning another language (Fookes 1997). Without technical language geology would not exist as a profession and scientific discipline. It is the responsibility of the geologist to judge the correct tone and technical content, and to make sure that jargon (unnecessary and extraneous use of technical terms) is not used when communicating with others. Levels of communication vary depending upon the education of the recipients; with specialists the communications can be highly technical, but with schoolchildren they must be in plain language. In mixed audiences using the correct level of technical content is difficult and needs to be considered carefully before engagement takes place.

Existing information and guidelines

There are relatively few reports available for geologists aimed specifically at communication. Publications that deal with communications usually refer to a variety of geological topics; for example, publications on geohazards and geological information include that by Forster & Freeborough (2006). Also, numerous websites now provide information on a range of geohazards (e.g. see the websites for the US Geological Survey, the Geological Society of London and the US Federal Emergency Management Agency). The material within these websites is useful for information on geohazards (landslides, mining, floods, tsunami, volcanoes and earthquakes).

Lyme Regis, on the south coast of England, and Ventnor, on the Isle of Wight, are areas with a high potential for landslides and have frequently experienced active landsliding. This has made the local councils aware of the need to communicate effectively with the public (including leaflets advising householders and the public) about the landslide hazards and what was being done to investigate and mitigate the effects of landslides (Cole & Davies 2002; Davis & Cole 2002; McInnes 2004).

In Britain, the shrinkage and swelling of clays during prolonged hot summer months frequently causes structural damage. Since the drought of 1976, the Institution of Civil Engineers and the Building Research Establishment have been proactive in raising awareness of the possibility for repairs that may be required as a result of subsidence damage (Freeman *et al.* 1994). The report by Freeman *et al.* (1994) provided information on the causes of subsidence, the distribution of clays susceptible to shrink–swell, what types of investigations to carry out and advice on how to make insurance claims. The increasing incidence of drought since 1976 and the greater awareness of the possibility of making claims for repairs to houses damaged by subsidence created a need for more information about the hazard of shrinkable clay.

In Britain, the communication of landslide and subsidence hazards has been facilitated by the production of planning policy guidance, including publications by the Department of the Environment (1990, 1996), Department of Trade and Industry (1996, produced by the Office of the Deputy Prime Minister) and Department of the Environment, Transport and the Regions (2000). These guidelines provide information on the possible geological causes of potentially unstable land so that this may be considered during the early stages of the planning, redevelopment or rehabilitation of land.

The Coal Authority provides coal mine search services to inform home owners and developers of the potential mining hazards associated with the legacy of past coal mining and brine pumping in Britain (Law Society 1994). Published information on mining and other geohazards in Britain has been provided by, for example, Geomorphological Services Ltd (1987), Arup Geotechnics (1992) and Applied Geology Limited (1993). Similar information published in the USA includes work by Muton & Shimabukuro (1974), Marts *et al.* (1978), Nuhfer *et al.* (1993), Creath (1996), Noe *et al.* (1997), Holcombe *et al.* (2003) and Mileti *et al.* (2004).

Communication in other professions

Communication is recognized as being important in professions other than geology. In the medical profession, for instance, effective communication is crucial between doctors and their patients. Medical jargon is rarely used, and if it is, it is explained. Professional guidance notes to help doctors communicate effectively have been produced; these include publications by Dickson *et al.* (1989), Audit Commission (1993), Ong *et al.* (1995), Hind (1997), Royal College of Physicians of London (1997), Williams (1997), the NHS Confederation (1997) and the British Medical Association (1998). Although much of the information contained in these papers and reports is aimed, obviously, at the medical profession and at the doctor–patient relationship, there are some generic concepts that can potentially be applied to the geological professional. The medical profession has recognized the problems that arise when communication fails, between staff, different departments, and doctors and patients. These observations are similar to those in engineering geology, mining, geoforensics and geohazards investigations, especially where large teams are involved, with different personalities from different technical, social and cultural backgrounds.

Perhaps the solutions provided to the medical profession have application to the geosciences?

Types of communication

All geologists should be competent in both oral and written communication. Geologists need to communicate with all age groups, a wide range of other professions and across cultures. Competence in communication is therefore a critical part of geologists' training and capabilities. There are two main ways by which geologists conventionally communicate: (1) spoken (conferences, workshops, seminars, lectures and meetings); (2) written (reports, memoirs, maps, scientific papers, technical notes, letters, e-mail and computer data).

Spoken communication relies on interpersonal skills and the ability to convey information effectively, confidently and consistently (often, consciously or subconsciously relying on body language). These skills are important when geologists are providing information on an impending geohazard. Written communications, such as publications, reports and maps, allow geologists to communicate with each other, but are not necessarily the most effective form of communication when geological information needs to be conveyed to another (non-geological) professional or members of the pubic, who may not necessarily be familiar with complex geological language.

Communication skills

Communication may be learnt by training so that geologists can become better communicators; training and the continuation of professional development (CPD) may provide the necessary opportunity. The type of communication training needs to be planned and considered with respect to the geologist's background and professional role as a geologist (e.g. a forensic geologist v. a mining geologist v. an engineering geologist). Training courses therefore need to be properly designed and 'fit-for-purpose' to facilitate the requirements of the geologist (or group of geologists).

Geologists also communicate not just to convey information but to create and develop positive inter-professional relationships. Communication involves the interaction of individuals. It may be entered into voluntarily or non-voluntarily and sometimes involves emotive issues. Whereas many geological investigations rely on technical sophistication, innovation and fundamental science, interpersonal communication is the means by which geologists communicate their findings. There are many ways geologists may develop good interpersonal relationships, but there are very few guidelines or publications on how this may be achieved. Circumstances will vary, but, in general, good relationships rely on some well-accepted characteristics (e.g. good manners, respect, laughing, compliments, friendliness and especially empathy, amongst many others). The good communicator must also be a good listener, using silence, reflecting, paraphrasing and non-verbal behaviour.

Geologists and communication with other professionals

Successful communication between fellow geologists is important to ensure that clients and other professionals do not receive conflicting, confusing or contradictory information. In civil engineering, for example, a structural engineer may be offered different advice from a geotechnical engineer or an engineering geologist, which is probably frustrating for the structural engineer. This situation may have arisen because it reflects the different training for the two disciplines; it may also be traced to the fact that many engineering geological decisions are based on judgement and interpretation. A co-ordinated and integral approach is therefore required in such circumstances for the outcome to be successful.

Geology is crucial to the civil engineer, who requires factual geological information on the ground in which he is working, the engineering characterization of the ground conditions, and information on groundwater and hydrogeology. The best services an engineering geologist can provide to a civil engineer are to get the geological characteristics of the site right (Fookes 1997). Once the geology is understood, this needs to be then clearly communicated to the engineer who will use the information to help make decisions.

Civil engineers, although technical subject matter experts, may not necessarily be familiar with the complex technical terminology used by engineering geologists. Too much geological terminology may potentially cause the engineer to become frustrated. Engineering geologists have the ability to make sound, rational decisions, based on partial and imperfect knowledge. Engineering geologists must reply on judgement and therefore this introduces a degree of uncertainty, as a result of 'gaps-in-knowledge'. These judgements are based on the geologists' training, observation and experience, and communication skills. Engineering geologists must therefore make accurate judgements and communicate the information to clients and engineers. Visual aids such as maps, cross-sections, photographs, drawings and 'back-of-an-envelope' sketches are often the solution during informal communications between the geologist and the engineer (Fig. 1).

Fig. 1. Communication with a range of other professionals and technical specialists. Top left, geologists discuss volcanic hazards during the inspection of lava flows, in the Valle del Bové, October 1992 eruption of Mt Etna, Sicily. Top right, discussions with mining engineers, surveyors and strata control experts at the adit entrance to a small mine in Kashmiri Pakistan in the Karakoram Himalayas. Bottom left, mining geologists, mining engineers and geologists from the Pakistan Geological Survey inspect maps during an exploration survey at high altitude in a remote part of the Karakoram–Himalayas. Bottom right, engineering geologists investigate a 4 m high, 4 km long, fault scarp in the South Wales Coalfield, discussing mining subsidence and fault reactivation mechanisms.

Forensic geologists, police officers and police search advisors who search the ground for murder victims' graves (Donnelly 2000*a*, *b*; Fenning & Donnelly 2004), may also find communication challenging (Fig. 2). This work involves teams of multidisciplinary experts such as geologists, anthropologists, botanists, victim recovery dog handlers, remote sensing aerial assets, behavioural profilers, clinical psychologists and military personnel. These searches are usually co-ordinated and managed by a Senior Investigating Officer (SIO). A conceptual geological model of the ground may be developed by the geologist to provide information about the target's age, size, geometry, expected depth of burial, time and duration of burial, and physical, chemical, hydrogeological and geotechnical variations compared with the surrounding ground. This information may then be used to determine the correct search strategy, the appropriate choice of instrumentation, and the optimum method of deployment. To successfully carry out such an operation, the main challenges are not necessarily technical but communication. The geologist conveys all of the above technical information to the SIO and other experts. The police officer may have already a team of multidisciplinary technical specialists. How does the geologist fit into this system? At what stage does the geologist approach

Fig. 2. Top, geologists and police officers inspecting the ground in the Midlands, following the discovery of human bones (later found to be a pauper grave). Bottom, geologists and police officers search the ground.

the crime scene, to reduce the risks of any cross contamination? How can the geologist begin to understand crime scene management and crime scene investigation, and the strict police protocols involved? The SIO, already possibly overloaded with a range of specialists, now finds that he or she has to deal with yet another specialist, the geologist (Fig. 3). This may potentially be problematic if the process is not carefully planned and communicated (Donnelly 2003, Harrison & Donnelly 2008).

There is clearly still the need to improve communication between geologists and other professionals. It is essential that good channels of clear communication are developed and maintained. The interface with geologists and other professionals may often take place on a one-to-one personal basis. For communication to be effective both the geologist and the other professional must be able and willing to give and receive information.

Geologists and communication in a multicultural world

Geologists, like other professionals, usually discuss and debate their findings, and consideration must be given to whether members of the public

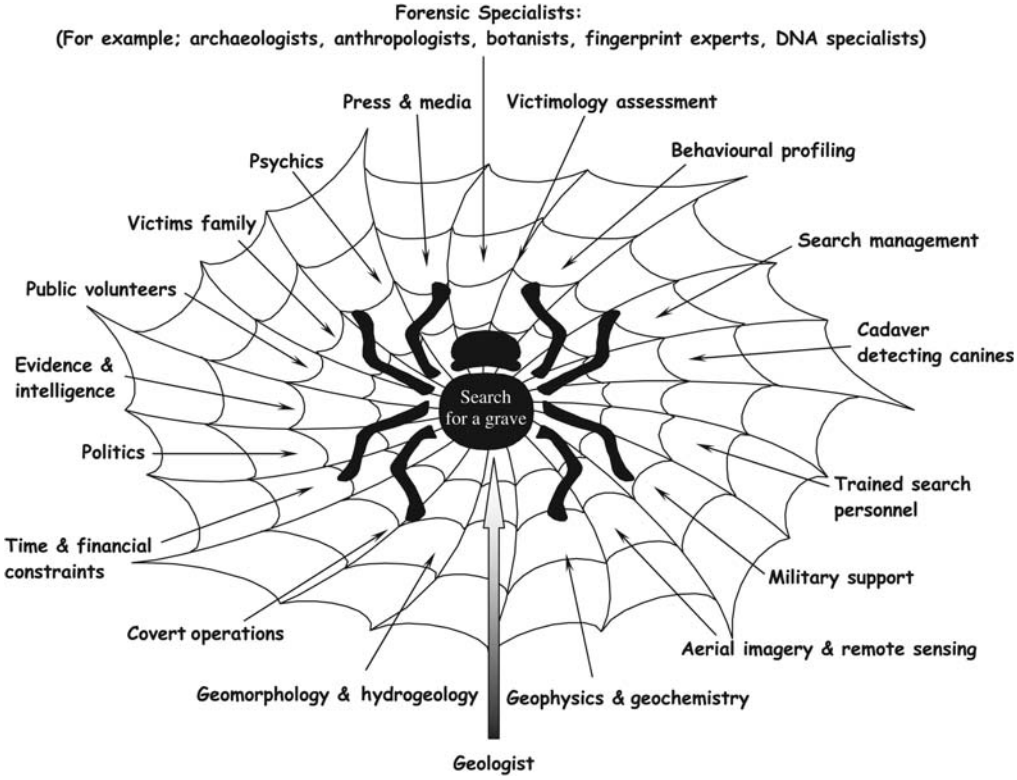

Fig. 3. The introduction of a forensic geologist to a complex, multi-disciplinary police search team must be carefully co-ordinated and properly managed. The geologist must be able to effectively communicate with the other subject matter experts, be aware of his/her limitations and understand the role and capabilities of the other experts (modified after Donnelly 2000*b*, in Harrison & Donnelly 2008).

(Anonymous 2002), or the client, should be part of those discussions. Often the recipient of geological information requires only a decision, and may not necessarily be concerned about the details of how that decision was determined. During the monitoring of a recent volcanic eruption, for example, some members of the public were present during scientists' debrief, discussions and debate. It was originally envisaged that this would strengthen and improve relationships between scientists and the public. However, it had the opposite effect, because the public considered the scientists' debates and discussions to represent uncertainty and inconsistency, which undermined some of the public's confidence. The communication of geological information to the public may be influenced by the following: (1) language barriers; (2) human influences, such as disinclination to ask (possibly because of embarrassment), anxiety, anger, forgetfulness, preconceptions, pride and age differences; (3) assumptions ('a little knowledge may be dangerous').

Each community, society and group of people has its own particular view of the natural environment and geohazards, although they may be subjected to the same events (Fig. 4). It is this view that needs to be very carefully considered before engaging with a community to discuss geohazards, consequences and risks. This will determine the type of language to use (technical or non-technical) and the manner in which to conduct the communication. Individual perception and public response is based on geohazards history, traditions, culture, religion, emotion, folklore, gossip, superstition, other non-scientific influences, knowledge about the risk, and experience. Individual judgement is based on previous personal experience of the geohazard rather than an objective, collective assessment of all the probabilities and consequences (Peltu 1991).

Effective communication is central, and this is particularly important when members of the public are being provided with information concerning potentially catastrophic geohazards.

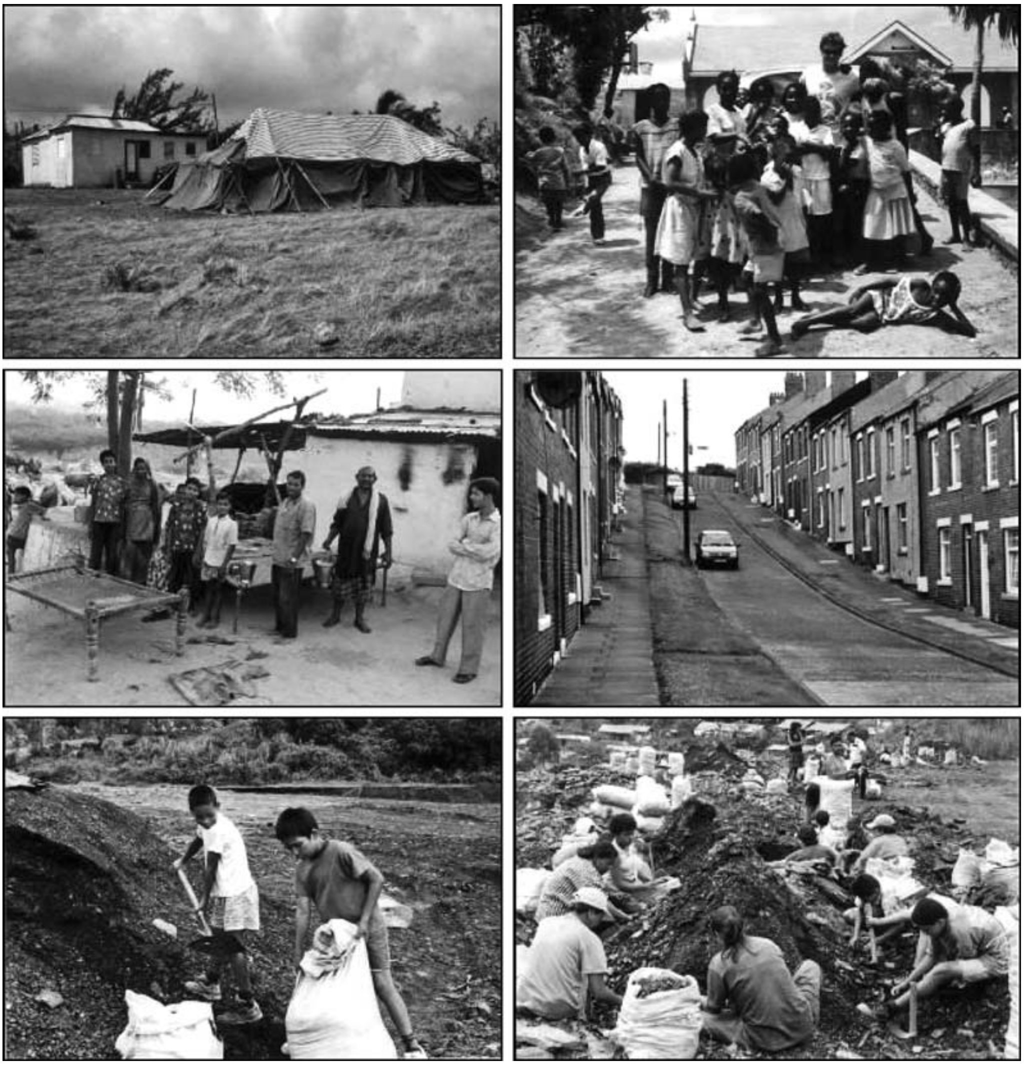

Fig. 4. The communication of geological information to the public, multicultural and multiracial societies. Top left, evacuation camps established in Montserrat, during the eruption of the Soufrière Hills Volcano, Montserrat. Top right, local residents at a Montserrat evacuation camp displaced by volcanic hazards. Middle left, farmers in Singrauli, India, affected by mining hazards associated with large scale open cast and under ground coal mining operations. Middle right, terraced houses in Easington, County Durham, affected by mining subsidence. Bottom left and bottom right, children, women and unskilled men who scavenge coal from waste tips in Antioquia, Colombian Andes. These communities and environments, where geological and mining hazards have negatively affected lives require the clear and careful communication of geological information to the public and interpersonal skills.

Geologists who work in multicultural and multiracial societies should have an appreciation and understanding of the different types and levels of communication that may be required with the public and non-specialists. Particular attention should be paid to local customs, which it may be important to respect. Appropriate preparation and adequate provision of language interpreters and bilingual translators may be required to improve cross-cultural communication.

Communication is an interpersonal social skill, not a technical one, and as such requires an appreciation of the emotional dimension of the situation both before communicating and as a result of its impact. For communication to be effective the geologist must identify and understand the needs of the target audience. This includes an assessment of their state of knowledge, any gaps-in-knowledge, their appreciation of basic science, their language, cultural values, age profiles, and domestic, political and language constraints. Careful consideration must be given to the background of the particular audience. In any situation, effective communication, in the opinion of the author, may be achieved by face-to-face meetings to engage directly with the recipients, audiences and/or other professionals. Audiences of mixed ages, race, religions and scientific background are likely to have different understandings of geology and geohazards. In these circumstances, good visual aids facilitate effective communication (this may include, for instance, maps, photographs, animations and video footage).

Once the target audience has been engaged, the information may then be transferred by verbal, written, electronic or visual means. When the public, clients and professionals have been given information on geohazards they will then need to be informed on potential strategies on how to mitigate or avoid the hazard (Fig. 5).

Feedback is a critical part of communication. Many people may react adversely to an authoritarian stance and need to feel they are 'part of the process', and/or 'in control'. Continuity is important; a single meeting may not be sufficient, as geohazards do not simply cease. There is likely to be the need for a programme of regular meetings, and it is important that the same information, advice and recommendations are given in a calm, clear, non-ambiguous and consistent manner, making sure that, whenever possible, technical language is avoided or minimized (or if used, then explained).

Good communication is important during the monitoring and prediction of volcanic eruptions. There are several examples of successes and failures. For example, Nevado del Ruiz volcano is located in the Andean Cordillera of Colombia, approximately 100 km NW of Colombia's capital city, Sante Fe De Bogota. On 13 November 1985, a Plinian eruption generated a series of pyroclastic flows, which interacted with the snow and ice that formed the summit ice cap. The rapid transfer of heat from the eruption, combined with the seismic shaking, generated lahars (mud flows) and avalanches of saturated snow, ice, felled trees and rock debris. These flowed along drainage channels and within 4 h had travelled over 105 km, descending 5100 m, leaving a wake of catastrophic destruction and obliterating everything in their path. The town of Armero was buried beneath a blanket of mud. Approximately 24 740 people were killed or missing, 4420 injured and 5092 made homeless (Fig. 6).

Geohazard investigations were undertaken at Nevado del Ruiz, prior to the 1985 eruptions. Previous pyroclastic flow deposits and lahars were mapped and their extent was known, accurate reports of historical events were recorded and, following a period of monitoring the volcano, advice was made available from Colombian and international scientists who participated in the investigations. In the months prior to the eruption, communications were established between geologists and the government. The geologists attempted to explain the significance of the observed precursory activity, which included low-intensity earthquake swarms, a steam (phreatic) eruption, explosions, ash-fall deposits and small lahars within 30 km of the summit. Geological hazard maps were produced over a month before the fatal event. The Colombian officials issued alerts to prepare for mudflows, but unfortunately these reports were not properly disseminated. Pyroclastic flows and surges were generated, but it was not announced that these events were significant. Information on volcanic hazards was met with scepticism by the local authorities and the population. An evacuation of Armero was considered to be unnecessary by the authorities (this may also have been influenced by the fact that it was night with heavy rainfall). The violent lahars came in two surges, the first cold, the second hot, and these engulfed Armero for at least 2 h. The catastrophe at Nevado del Ruiz and Armero was exacerbated by failures in communications, cumulative human error, misjudgement, indecision and bureaucracy (Williams 1990*a*, *b*).

Montserrat is a British dependent island located in the West Indies. The Soufrière Hills Volcano, situated in the southern part of this island, has been in a state of almost continuous volcanic activity for the past 13 years, since 1995, after being dormant for about 400 years (Druitt & Kokelaar 2002). The Montserrat Volcano Observatory (MVO) was established soon after the occurrence of phreatic eruptions on 12 July 1995. The eruption of the Soufrière Hills Volcano was an event for which the local population was completely unprepared.

Pyroclastic surges and lahars have radiated from the volcano, travelling along river gullies towards the sea and engulfing numerous villages. This has resulted in the loss of use of a large part of the island, including the airport, main jetty and capital town, Plymouth (a new airport and jetty have now been built; Plymouth has been evacuated of all its residents and is currently buried beneath volcanic deposits), and there were some fatalities (Donnelly 2007).

During the early stages of the eruption some of the islanders and scientists were conscious of

Phase 1: Identification and investigation of geohazards

Identify the types of geological hazards (e.g. lava, pyroclastic flows, earthquakes, lahars, flood, landslide, tsunami, subsidence). Design and implement a geological investigation to assess their potential consequences and levels of risk.

Phase 2: The audience

Consider the recipients of the geological information. This may include; giving considerations to their history, background, levels of knowledge, education, languages barriers, age, traditions, religion, emotion, folklore, gossip, superstition, individual judgements, understanding of science, cultural values, political issues and sensitive subject matters to avoid. Consider human influences such as; assumptions, anxiety, anger, forgetfulness, preconceptions, pride and disinclination to ask questions.

Phase 3: Engage

Consider how to best and appropriately convey the messages. This may be verbal, written, electronic or by visual means. This may include; for example; private meeting, public informal meeting, face-to-face meetings, lectures, use of the media (TV, radio and/or newspapers), use of video footage and other visual aids, photographs, maps, animations, letters, technical reports, fax, email, visits to a school or evacuation camp.

Phase 4: Transfer of data, information and knowledge

Consider how can geohazards information be most effectively delivered and presented so that the audience can understand. This may include; no, or restricted use of jargon and technical terms. Considerations must be given to personal image, appearance, body language, tone of voice, facial expressions and posture.

Phase 5: Empowerment

When people have been informed of the potential consequences and risks associated with geological hazards, they should be presented with strategies to deal with the geohazards (i.e. people need to feel in control of a hazardous situation).

Phase 6: Avoidance, mitigation and remediation

Advice may be provided on; awareness, preparedness, avoidance, emergency management, evacuation, mitigation, or post disaster rehabilitation in the aftermath of a geological hazard.

Phase 7: Feedback

Audiences and people should be invited to ask questions and to express their views and opinions. This may also serve as a test, to check if the correct message has been received and understood.

Phase 8: Continuity

Because most geological hazards may last for weeks, months, years or decades, a program of continuity is required so people affected receive regular, consistent and reliable information and advice.

Fig. 5. Conceptual flow chart to illustrate the main phases of communication during a geohazard investigation.

Fig. 6. Top left, the town of Manizales, Colombia, situated in the shadow of Nevado del Ruiz Volcano. Top right, view of the upper Lagunillas River valley, close the summit of Nevado del Ruiz. Bottom left, scoria, ash-rich pyroclastic flow deposits exposed on the upper reaches of Nevado del Ruiz. Bottom right, horizontally stratified ash, pyroclastic flow, pumiceous and mudflow (lahar) deposits on the walls of the Lagunillas River valley, exposed by erosion during the 1985 lahars that buried the town of Armero. Approximately 24 740 people were killed or missing, 4420 injured and 5092 made homeless. This was attributable, at least in part, to breakdown in communications between scientists and officials.

historical volcanic eruptions on neighbouring Caribbean islands. For instance, in 1909, the eruption of Mount Pelée on Martinique generated pyroclastic flows that killed at least 29 000 people. More recently, in 1976–1977, approximately 70 000 people on Guadeloupe were evacuated following a relatively small steam eruption on La Soufrière Volcano that lasted about 9 months. However, no major eruption followed and the evacuation was considered to have been unnecessary by many of the local people. Unfortunately, there was a breakdown in communications between the geologists, government and the public; no lives were lost but there was a significant negative economic impact on businesses and farms (Robertson 1995).

The move towards the evacuation of much of the population of Montserrat resulted in a situation where the communication of geohazards to the government and public was very important. In the early stage of the eruption on Montserrat different types of communications were established with the public. These included the daily issuing of statements via the media (TV and radio), regular meetings with community representatives and the issuing of newsletters (Fig. 7). During the early stages of the eruption the author experienced the benefits of personal engagement with the local community (Fig. 4). This supported more formal volcanic hazards announcements provided by the MVO, sometimes via the media and Government of Montserrat. An appreciation of interpersonal and social skills was necessary for creating an environment of trust within which a dialogue could be established to convey the necessary messages of the nature of volcanic eruptions and their implications for those threatened by them. This approach demonstrated the need for social and interpersonal skills as well as technical and scientific expertise, for the effective monitoring and communication of volcanic hazards.

During the eruptions of Mount Pinatubo, in the Philipines, in 1990 (where approximately 250,000 people were evacuated) and Rabaul in Paupa New Guinea in 1994, good communications between geologists, the authorities, and the population resulted in a positive response from the people affected by these volcanic eruptions. This is likely to have saved many thousands of lives (McGuire 1998).

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Fig. 7. Examples of leaflets and newsletters produced by the Government of Montserrat to help with the communication of information on volcanic hazards to the public. Reproduced by kind permission from the Government of Montserrat.

Fig. 8. Communication with the media. Top left, during the monitoring of the Soufrière Hills Volcano, Montserrat, for the production of an international TV documentary. Top right, and bottom left, journalists photograph a geologist working at a crime scene. Bottom right, local TV news crew interviewing a geologist describing mining hazards and their impact on the environment.

Geologists and communication with the media

Geologists sometimes have to communicate with the media (Fig. 8). Geologists are not conventionally trained to deal with journalists and so their responses should be carefully considered, so that the intended message is put across clearly, factually and without sensationalism (however, post-interview editing can change this). Failure to communicate the geologists' messages accurately may result in the media (and therefore the public) being given an erroneous estimation of a geohazard or misleading information about a sensitive police investigation. If available, press officers or public relations specialists should be consulted prior to any interaction with the media, to obtain appropriate advice and to be made aware of any broader issues (Nield 2008).

Before geologists accept invitations by the media they should make sure they understand whether the interview may be recorded or live. Recorded interviews may give the opportunity to rehearse or review an interview before it is broadcast or reported (although this is not always the case). Live interviews do not give the opportunity for rehearsal prior to broadcasting or for the correction of mistakes. It is therefore essential that the geologist prepares for the interview, understands something about the usual programme, including its aims, objectives and target audience. This will allow answers to be prepared beforehand in the context of the interview. Geologists need to decide before the interview takes place exactly what the key points will be that they are trying to get across in the message. About three or four main points should be identified.

During interviews with the media and the public, geologists should come across as being confident and positive. The information given should be simple, clear and non-contentious, and ambiguity should be avoided. Jargon should not be used, but if geological and other scientific terms are used, then these should be explained in non-technical terms. During live interviews any mistakes made must be corrected during the interview. When being interviewed on television or for the production of a documentary, personal image, appearance, body language, tone of voice, facial expressions and posture are just as important as the verbal messages.

Speaking with the media (and public) gives geologists the opportunity to raise the profile of geology. During public speaking, it is always advisable to match the talk to the interests of the audience. The communication of geological information to the public, and the public promotion of science, can be entertaining and enjoyable. Magazine articles, newspapers, lectures and TV documentaries regularly focus on geology and in particular geological hazards. This enhances the public understanding of geology. What is more, geology as a profession depends on the next generation and constant flow of ‘youngsters’, and therefore professional geologists perhaps have a duty to participate in the public communication of geology (Donnelly 2002*a*). Working in such an interesting profession, it is not too difficult to supplement such talks and presentations with enthusiasm and impressive images of geohazards; always guaranteed to captivate audiences and the media. On occasions, some of these presentations have inspired tomorrow’s generation of geologists. Further information on communicating with the media has been published by, for example, White *et al.* (1993) and the Royal Society (2000).

Summary

Communication of geological information is usually preceded by scientific (geological) investigations, the results of which are then conveyed by the geologist to the recipient. In many respects the communication of technically complex geological information is usually more challenging that the geological investigation itself. This is made more difficult where the socio-cultural background and language are markedly different from that of the communicator. The failure to effectively communicate geological information may blight land or have catastrophic consequences.

The geologist must make sure that the information is effectively and accurately communicated. Communication usually takes place by spoken or written means. A geologist relies on interpersonal skills, training and expertise to overcome any potential obstacles that may hinder good communication. Good geologists are not necessarily good natural communicators. The failure to effective and accurately communicate geological information, no matter how accurate and reliable the results of a geological investigation, may reduce the reliability of the information being provided.

Communication is a social skill, not a technical one, for the impersonal transfer of data and information. The most effective method of communication is the use of clear, simple, unambiguous, non-technical language. Visual material can facilitate effective communication, especially to a non-technical audience and other professionals with little or no knowledge of geology. The transfer of knowledge, to be wholly effective, needs to be done with confidence and consistency. The good communicator must also be a good listener, using silence, reflecting, paraphrasing and non-verbal behaviour. If possible, there should be feedback from the targeted audience (or individual).

During the monitoring and prediction of geohazards (e.g. volcanic activity), one of the important challenges is to understand the popular, public perception of the hazards and threat. The real challenges are to communicate the likelihood of an eruption and to call for an evacuation; this is often a very difficult decision, usually much more difficult that the science itself.

The accurate communication of information relating to geohazards by geologists to the public is critically important. Throughout history there are many examples where geologists got the science and communication right, got the science right but the communication wrong, or got both the science and communication wrong.

When working with the police, the forensic geologist must be aware of the limitations of his or her experiences and be confident to communicate with a multidisciplinary team of forensic investigators and police officers.

Communication with the media (and public) gives geologists the opportunity to raise the profile of geology. Media training and awareness is recommended before engaging with the media. Responses need to be carefully considered, so that the intended message is put across clearly and, factually, without sensationalism. Recorded interviews may give the opportunity to rehearse or review an interview before it is broadcast or reported. Live interviews do not give the opportunity for rehearsal prior to broadcasting and for the correction of mistakes. Information should be simple and non-contentious, and ambiguous jargon should not be used, but if geological and other scientific terms are used, then these should be explained in layman's terms. When addressing the public and media, personal image, appearance, body language, tone of voice, facial expressions, persona and posture are just as important as the verbal messages.

This paper has relied heavily on the author's professional experiences during the monitoring of volcanic hazards, mining hazards, exploration, geotechnical investigations and working with the police in many parts of the world. This paper has highlighted some key issues and has drawn attention to the importance of communication between geologists, and with other specialists, the public and the media. These experiences suggest that communication should be more formally taught, perhaps at undergraduate level with advanced (CPD) communication courses available to practising, professional geologists. It is throughout the geologist's career, however, and from experiences that the real skills of communication are tested and developed.

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