Mapping, Drilling and Geological modeling

27 April 2010

Mark Osterberg, Tom Bidgood and David Thornton

MineMappers

Mine Mappers, L.L.C.
2114 West Grant Road, Box 114
Tucson, AZ 85745

Table of Contents

Table of Figures

"There is no substitute for the geological map and section - absolutely none. There never was and there never will be. The basic geology must come first - and if it is wrong, everything that follows will probably be wrong" - Wallace (1975) Mining Engineering, 27, 34-36.

Background

Modern mines are controlled by elaborate and detailed plans constructed with the use of high-end engineering programs like Mintec's MineSight or Maptek's Vulcan or others. Engineering and financial plans are built within these programs on geological, geotechnical, metallurgical, hydrological, environmental and assay models developed from mapping and drilling programs. Laboratory performance is routinely subjected to audit and overview. Geological programs, including drilling methodology and sample collection procedures are rarely audited and reviewed. If the geology is wrong, there is every chance the engineering and financial models will fail.

In part, the reticence to audit and review geological programs is a function of the individuality of each and every mining property. No two mineral deposits are identical and geologists have resisted the mechanization of geological evaluations. Nonetheless, the requirements of modern mining mean that systematic protocols and procedures must be followed if some means of data quality assurance and quality control are to be maintained. The discussion that follows lays out a means for such programs.

Geologists

Mapping and logging fall primarily into the purview of geologists. Field work may be physically demanding and logging can be an un-exciting activity. These facts mean that a significant quantity of such work is performed by junior level experienced geologists. The retraction of geological staffs over the decades means that many junior geologists do not receive the mentoring and industry training that was commonplace a generation ago. This leads to the unacceptable situation where the most inexperienced folks are responsible for the collection of data that underlies everything else that happens in the engineering and financial departments. If the right data is not collected or if the data is bad, the information will be wrong and the models will have no correlation with reality.

Mapping protocols

Geological mapping traverses are conducted along benches, drill roads, other undesignated access and outcrops. Outcrop distribution, shape, lithology, structural features, alteration and mineralization are recorded in conventional fashion on paper or digitally with hand-held, ruggedized computers at field scales that appropriately match the distribution and area of individual outcrops (i.e., a field scale that captures all relevant detail under the purview and scope of the project). Samples are collected for petrographic, geochemical and geophysical purposes. Descriptive notes, including color, texture, mineralogy, fossils or any other noteworthy observation are recorded in field books or digital recording devices.

Attitude measurements are captured directly into hand-held GPS units and downloaded directly into spreadsheets. Sample locations are likewise captured digitally using GPS units. Additional information recorded on the map sheet and in the handheld GPS may include historic mine workings, mine waste dump locations, drill hole collars, roads and any other features deemed significant.

Paper field sheets are digitized and matched to georeferenced aerial photographs and detailed topography maps in GIS software. Individual outcrop locations will be modified and adjusted as necessary to tightly match the base maps. Accuracy and precision of outcrop locations, using this technique, is typically 2 ± 1 meter. Digital devices, slaved to differentially corrected GPS units can achieve tighter accuracy and precision.

Individual field sheets, with outcrop features are compiled daily to a master sheet. Any historic geological mapping and drilling information that is available will be checked and may be merged with new data generated in the field and used to supplement the construction of updated geological maps.
Next, geologic contacts and through-going faults are tentatively drawn on the printed outcrop maps and a folio series of working cross- and long-sections, incorporating available drilling information, is developed to work out the relationships between outcrop, geological contacts and structure, producing draft geological maps. The sections are oriented to provide clarification to complex geological problems and do not necessarily line up along grid lines.

The draft geological maps and the geological sectional models are proofed in the field. This usefully and reliably identifies problem areas that may then be re-evaluated and reconciled in the field and in section.

After passing field and sectional checks, these products are finalized as hard copy for study and evaluation and as 2-D and 3-D digital files, suitable for import into engineering modeling software as well as to digital databases.

The completed geological map is the first and most powerful tool for checking the veracity of any geological model. One can hold a map in hand and visit individual outcrops and observe. If the subsurface model doesn't honor surface geology, it cannot be correct.

Core Logging and Sampling Protocols

Core is placed in core boxes at the drill rig, as soon as it is removed from the core barrel. Each core box is labeled with the project identification, the company name, the hole identifier and the from and to depths of the core contained in that box. Depths are measured and recorded by the drillers to the nearest tenth of a foot or meter. Drill runs are separated by a wooden or plastic blocks labeled with the drilled interval length and the actual recovered sample. Intervals of no recovery are labeled as NR. Mis-latches and other mishaps common to core drilling should also be similarly recorded on blocks placed appropriately in the core boxes.

Core is picked up from the drill rig regularly and transported to the logging facility where it will be logged and photographed. Core will be laid out on well lighted tables, permitting efficient and consistent logging. Sufficient table space for an entire hole is preferred, at least 60-meters of table space is minimally required.

Logging is best carried out in a systematic, step by step fashion. First, core blocks placed by the drillers in the box are recorded and checked for correct position and labeling. Incorrectly loaded boxes may be re-loaded, illegible blocks rendered legible and recoveries, RQD and other project specific geotechnical data measured. This step provides a check on drilling integrity, drill performance and sets up the core for geological logging and sampling.

Next, lithologic contacts are located and characterized. Each lithological units color, texture and mineralogy are specifically noted. Bedding, foliation, veins and any other planar features are located in terms of depth and attitude relative to core axis is recorded. Likewise, alteration type, intensity and extent are recorded in similar manner. And, specific tabulation of the proportions of ore, gangue and alteration mineralogy is also recorded. Lastly, structural features are measured and characterized, including structural attitudes.

After completion of geological logging, the geologist marks intervals on the core and in the boxes for assay, density determination, petrography or other specialized analyses. Sample intervals should not cross lithological or alteration type contacts. Sample identification and intervals must be recorded before any material is removed from an individual interval.

Next, each box of core is photographed before any sample is collected. Lastly, a sample dispatch form is prepared and core is then shipped to the laboratory for sample preparation and assay.

In most cases, core will be halved or quartered. Core not needed for assay, geochemical, or petrographic purposes is stored in weather and varmint proof facilities, to the extent that is possible.

Rotary and Reverse Circulation Logging and Sampling Protocols

Samples from Reverse Circulation (RC) and rotary drilling are generally collected on five foot intervals. Samples at the rig travel out of the drill hole and through an adjustable wet splitter, which can be set to capture a larger or smaller percentage of the total volume of cuttings depending on sample recovery and groundwater flow. The splitter is adjusted such that the sample can be captured in a five-gallon bucket. A six- or eight-inch diameter kitchen strainer is placed on top of the five-gallon bucket to capture a small volume of representative sample from each interval which is then used to fill chip trays for geologic logging. After chips are caught in the strainer they are initially shaken or rinsed over the splitter. Chips are then rinsed in relatively clear water and placed in the proper interval in the chip tray. Hand sorting of chips is not permitted. When clay zones or alteration is encountered the clay is <u>not</u> washed out of the chips. Chip trays should be labeled up with hole name and footage on the top and the ends of the box with the -TO interval for each of the divided intervals insides the chip tray.

At the end of each twenty sample run, an additional duplicate field check sample is collected. This sample is typically collected on the first interval, then the twentieth and each succeeding twentieth multiple interval. The bag for this field duplicate sample has the same markings as its mate but it should have an “A” after the footage. When a hole is being drilled for dual purposes, such as exploration and metallurgy or exploration and environmental, two or three samples are collected per sample interval. These samples are split out of the total cuttings return using the wet splitter in order to ensure that each sample is representative of the entire interval.

A proportionate quantity of chips should be placed in the chip tray only if sample is bagged for assay. If sample is not bagged, chips should not be put in the chip box for that interval and the box must be marked for no sample.

Samples are picked up from the drill rig daily and are transported back to the logging facility where each sample bag is inventoried on a sample tracking sheet and placed in a temporary storage container. The storage container is locked at night.

Logging of cuttings from reverse circulation and rotary drill programs follows core protocols without the means to collect attitude information from either lithology or structures. Location of contacts and structures are also limited to drilling intervals if specialized sonic, optical or geophysical open hole tools are not utilized.

Circumstances of poor recovery conditions or any unusual drilling conditions should be noted by the driller, including intervals where voids and back-filled workings are entered and exited.

Logging forms

Logging forms are used to enforce systematic logging of drill core and chips. Electronic forms that put logging data directly into a database serve the same function as a paper log but have the advantage of immediate data availability, on-the-fly QA/QC and elimination of most transcription errors.

Setting up an electronic logging form takes some aforethought. Time must be spent in the field and in the core shack to familiarize loggers with the inherent variation in lithology, alteration and mineralization for all rocks encountered in the project area. Attention must be paid to contact relations and the effects of alteration and mineralization on rock type determination. Exposed structures must be examined and cataloged to determine how faults vary-whether they are clean and sharp or broad zones of structural disruption or combinations thereof.

Master tables must be built that describe and document geological features. A table must exist that provides a code and a name for each rock type, based on color, texture and mineralogy. In the same way, master tables for alteration, mineralization and structure must also be developed before logging of new material may be undertaken. These tables provide the logger with a ready reference, provide auditors with a clear understanding of how and why certain units were logged and recorded and greatly simplify the reporting process.

This work helps to eliminate coding busts between surface and subsurface data sets and pays big dividends for 3-D modelers. Experience has also shown that team logging using electronic logging procedures is 2- or 3-times more efficient than the traditional assignment of a drill hole to a single logger. If a team logs all the holes, the give and take between geologists will work itself out in the same manner for each log and the chances of inconsistencies will be greatly reduced.

Coding

Coding scripts are run to assign lithological, alteration and structural codes to each logged interval. Coding is assigned solely on the basis of physical properties, hence the critically important requirement for color, texture, mineralogy and other physical property observations in the logging procedure.

Sample Transfer

Sample bags should be laid out on-site in correct order to simplify pick up and noting of missing samples. Duplicates should be placed in sequence with the samples. Samples are then placed in shipping containers for safe and efficient and secure transport.

Drilling wet in freezing temperatures presents added difficulties. Plastic sheeting, or other impervious barriers, should be placed between layers of samples to avoid the freezing together of a number of samples.

Sample tracking sheets must be maintained and must include information for missing samples, total depth and date.

Blanks and Standards

Blanks, standards and duplicates are used to assess the laboratory performance, accuracy, precision and repeatability of assay data. Blanks serve to assess the degree of contamination in the laboratory and as a means to determine how well run are routine laboratory procedures. Standards are used to determine the accuracy and precision of the analytical data and duplicates are needed to characterize the inherent variability of the actual sample. A well conceived and well run blank, standard and duplicate QA/QC program provides a high degree of confidence in assay results.

Certified commercial blanks, standards and contractor-generated field duplicates are inserted into the sample stream and in the best programs, are inserted blindly by a third party, not affiliated with the company. These blind check samples are inserted at a rate of 7.5-percent standards and 2.5-percent blanks and 5-percent field duplicates. The assay lab also must insert blanks, standards and lab duplicates, typically at a rate of 7.5-percent. Finally, an extraction of the 5-percent of the sub-ore-grade and ore-grade subset of the data should be sent to a second, referee laboratory for analysis. Results are then compared to original assay results. Results of all analytical test work should be reviewed by a designated qualified person (QP).

Record-Keeping

Clear chain of custody procedures must be established for assay samples. Records must be maintained for each step and handling stage. Dispatch forms must be signed when samples leave the property for the laboratory, when samples reach the laboratory and when rejects and pulps are returned after completion of assay work. It must be possible, at any point in process from sample collection to final acceptance of fully vetted, QA/QC assured assays to determine, with a minimum of effort, who was responsible for the samples, where the samples were physically located, when they were received and analyzed by the laboratory, how and what analyses were performed, how reject and pulp logistics were handled and how and when assays were appended to the database.

Storage of pulps and rejects should be in weather and varmint-proof facilities to the extent that is possible. Inventories need be well maintained.

Database Validation and Integrity

The whole point of collecting geological data is the construction of a drilling database that may be examined for geological information. The completeness and accuracy of a database are of prime concern. In addition, preparation methodology, analytical technique, sample compositing protocols, contamination and other unresolved issues may affect database quality and usefulness.

Validation and integrity checks of need be focused on four data-sets: drill-hole collars, down-hole survey, assays and logging.

Drill-hole collars

An extract of the drill hole collar file is taken from the database and imported into an Microsoft Excel spreadsheet where the surveyed collar data is compared to the original collar information. This may require an electronic compilation of paper hole collar records. Any discrepancies are reconciled to the original records.

Down-hole surveys

Digital copies of modern down-hole survey records are compared to the data in the database. Older, paper down-hole survey data is entered into a spreadsheet and compared to an extract of the database. Differences are reconciled to the historic records.

Assays

For historic holes with assay certificates a check of 10-percent of the historic data should be done. Assays from the certificates need to be entered into a spreadsheet and compared to the database. Differences are reconciled to the assay certificate.

Logging

Several separate checks are performed on the geology logged data. The logging data is checked for gaps and overlaps. Apparent non-reconcilable data in different fields for the same interval are evaluated on an interval by interval basis from any available physical material from the interval in question and a correction made if needed.

The last record of logged geology is compared to TD of the hole to insure that all intervals of the hole have been logged.

Coding of the geological data is validated initially by 3-D comparison with adjacent logged holes. Final validation is built on comparison with re-logs of randomly selected holes. Approximately 10-percent of holes should be re-logged for coding validation.

Discussion

Geologists collect geological data and interpret it. The users of geological information, mining engineers and business professionals, are generally not interested in the data itself and only interact with the interpretations that geologists have made.

Mining engineers speak MineSight or Vulcan or Datamine and don’t generally speak geologist. Geologists must build models that the engineers need and to do so software limitations and capabilities must be respected. Problems arise when geologists forget that software needs either/or and not both/and.

The objection might be fairly raised that sometimes geology does not lend itself to either/or. For example, sometimes faults do just end. In this case, other 3-D circumstances must be in operation. Ductile deformation, growth lines or other geological processes must be called on to satisfy geometry requirements. If either/or can’t be seen, the geology is not understood well enough to model for engineers.

Databases that do not include adequate metadata content are essentially useless. The ones that have missing spatial relationships are useless. Missing drill collar coordinates and interval limits and missing XYZ locations for map annotation render observations as meaningless is if the holes were never drilled or the mapping never completed. Almost as bad are geological observations where a clear, unambiguous statement is not recorded. For example, “the rock might be a quartz monzonite” is not acceptable in the modern digital world. If the geologist who makes the observation can’t correctly identify something, the poor computer driver certainly can’t. In such cases, the programs accept a rock type of “unknown”; they can’t accept a rock type of “might be quartz monzonite”. Assay tables without units or analytical details are not acceptable to auditors and regulators and are a danger to modelers.

Less critical, but annoying to the point of distraction are conditions that prevent the utilization of queries and filters in databases. Examples are misspelled words, mixing of data types, abbreviations without keys and jargon and the commonly used shorthand “As above”. If such features infest a database, it might be better to scrap it completely and start over with resultant loss in productivity.

The inadvertent use of Microsoft Windows operating system reserved characters also has detrimental effects for modeling databases. The keyboard characters / \ ? % * : “ < > and . have specific MS Windows functions and when used limit the dynamic usefulness of the database.

The point is that geological observations record color, texture and mineralogy. Everything else is an interpretation based on these data. If such descriptions occur in a database, queries may be utilized to consistently and rigorously identify a pale gray, porphyritic, plagioclase-K-feldspar-quartz-biotite rock in core or in hand sample or in outcrop as a quartz monzonite porphyry in every situation and circumstance. For geological modelers, this means that data points from core, chips, surface samples, trenches, outcrops, bench faces and any other exposures can be consistently coded.

Historic, pre-computer-era maps and sections would often just end. Faults would go from a solid line to a dashed line to a series of dots and then fade into nothingness. Rock types would smoothly end towards the edge of the paper. Modern computer programs, especially the high end engineering software, require closed polygons and solids or they crash or produce incorrect results. Maps and sections must be closed.

Obvious issues arise from projecting beyond the limits of drilling. Nonetheless, volumes cannot be measured if polygons do not close. If the field geologist doesn't make the call, the less qualified digitizer will have to make it.

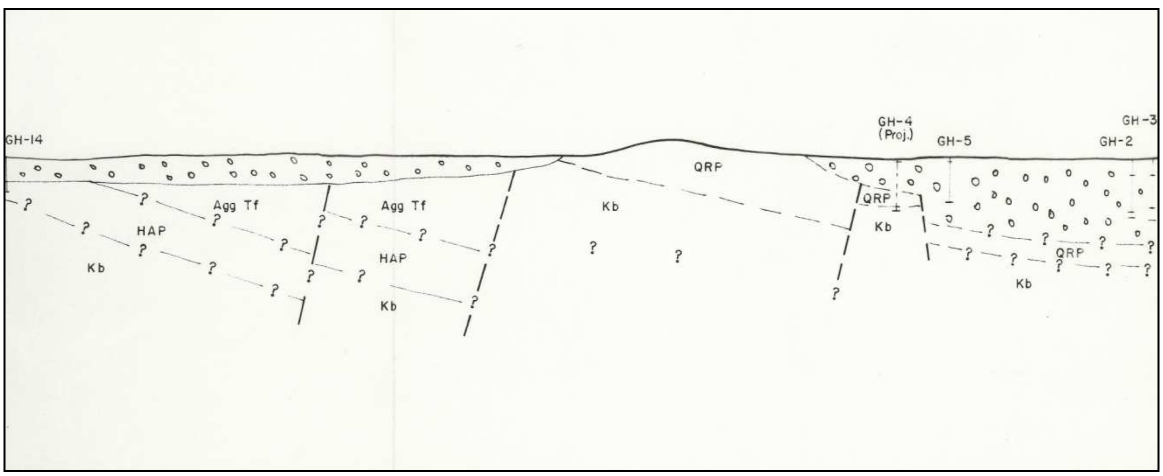

Figure 1. Pre-computer era cross-section.

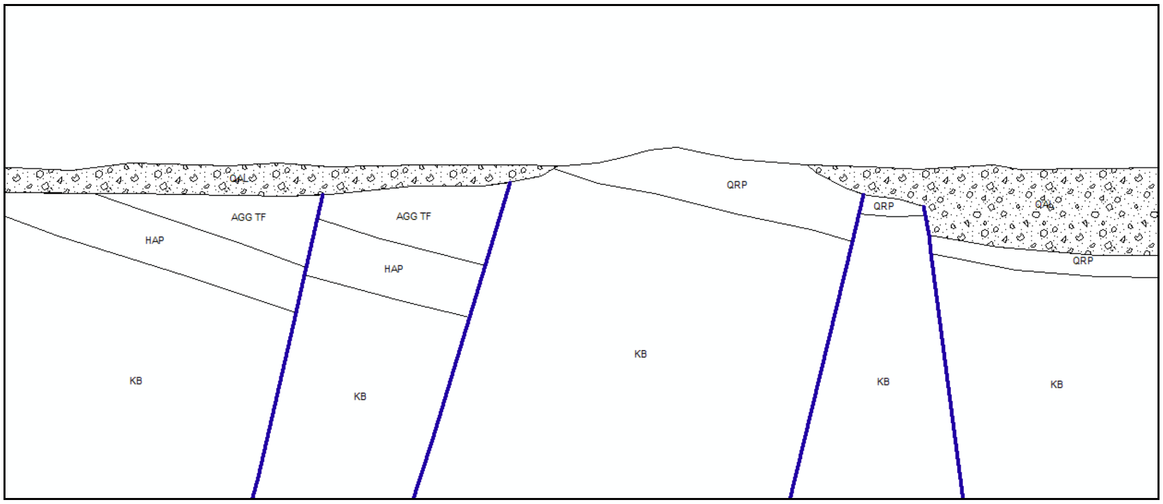

Figure 2. Post-computer era cross-section

Geologic relationships in the vicinity of most ore deposits are complex and hard to understand. Companies may find themselves in situations where the cost of junior staff is attractive to the point where a decision is made to trade dollars for quality assured, quality controlled geology. In the end, this almost always results in re-do’s and geological costs may be substantially higher than if experienced, well-trained geologists did the work in the first place.

Conclusion

Geology is the foundation of every mining project. There is no substitute for good geology-absolutely none. Accurate and precise maps and sections and drill logs make for clean and tight 3-D geological models. Good geological models lead to good engineering designs. Good engineering designs maximize mining efficiencies. Maximized mining efficiencies improve company profitability.

Seasoned, well-trained geologists are an advantage to any project and program. Geologists who understand a particular ore-type model, like Climax type molydenite deposits or porphyry copper deposits or Carlin-type gold deposits before project inception can much more efficiently, and cost-effectively organize, run and interpret program results so they are meaningful and useful for any client.