JOHNSTONE, W.P. Effective multi-dimensional orebody modelling: A key component of the mining value chain. *Application of Computers and Operations Research in the Minerals Industries*, South African Institute of Mining and Metallurgy, 2003.

Effective multi-dimensional orebody modelling: A key component of the mining value chain

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The computer assisted generation of geological models to represent the geometry of, and grade distribution within, orebodies is a rapidly growing area of the geological profession. Such models are increasingly used as a necessary starting point in determining the mineability of mineral deposits in terms of practical mine design and economic considerations. The transition from traditional techniques such as field or underground mapping and the manual calculation of grade and tonnage estimates, as well as related activities such as the interpolation of cross-sections, the use of stereographic projections, core logging and hand contouring, to computerized applications, is by no means complete. In fact, many geological professionals deliberately avoid the use of computer simulations based on the perception that the resulting models are simplistic and that their construction is not founded on sound geological principles. The purpose of this paper is to assess current thinking on this topic by considering; (a) an overview of advances in the drafting of geological maps, (b) the theoretical basis for multi-dimensional geological modelling, (c) the case for combining traditional and modern techniques, and (d) the benefits to the mining value chain.

Introduction

'Geological maps, both surface and underground, do not meet the needs of modern mining operations', and, 'computer generated geological models used on mines do not accurately represent the complexity of the orebodies being mined'. This is a common circular argument currently being debated among geological professionals in the mining industry. Few would argue that data collection tasks such as field mapping and core logging remain the foundation of geological interpretation, even so, it has always been true that the quality of data collection is variable depending on circumstances such as the natural conditions and the human element. A fundamental principle of field mapping is to represent the actual or visible geology as accurately as possible, and any small inaccuracy resulting from data collection is compounded at each new level of interpretation. The situation is no different for the construction of a computer generated geological model. The model has to be 'built' using accurate spatial information whether the data represent mapped contact positions, structural measurements, drillhole intersects, topocadastral survey stations, geophysical measurements and so on. A poorly drafted map is as flawed as a poorly considered geological model, except that the latter will almost certainly have a more direct consequence on the estimation of the size (tonnage) and grade of an ore deposit. The key is to reduce uncertainty by applying as much geological input during the creation of a model, and to develop tools to validate and quantify the reliability of a model (Saksa, 1997; Budding, 1997).

Hand-drawn to digital

Accurate geological mapping is a pillar of the geological sciences, many of the highest quality maps on record were drafted without the use of set squares, scale rulers, clutch pencils and other 'modern' instruments. Aside from these classical examples, it is true to say that hand drafting has evolved over the past decade for the better, and that this has led to improvements in the accuracy of geological maps. Why not view the more recent evolution from hand-drawn to digital maps in the same way? For many field geologists, the digital capture of information collected in the field and the subsequent drafting of geological maps using Computer Assisted Drafting (CAD) software has not been a positive experience, and the resulting maps are considered to be over-simplified. This situation has come about largely because the field geologist has, for one reason or another, passed the data on to an independent CAD specialist who does not have an adequate appreciation of the geology. The outcome is that, subtle yet critical observations such as terrain, level of exposure, quality of outcrop, stratigraphic relationships and structural complexity have often not been incorporated into the geological map. When these omissions are combined with changes in scale, and or projection, the inaccuracies are compounded and the resulting map does not meet the requirements of the field geologist. Invariably, the negative perception of digital drafting 'tools' stems from poor or incorrect application. Once this point has been appreciated, the future should see a move towards field geologists being involved in, and preferably performing CAD tasks.

Geographical Information Systems (GIS) are another level of software applications which have been effective in the geosciences, particularly the remote sensing and image processing functionality which is typically used in mineral exploration. In remote sensing, the information collected is purely digital, but without the input of a geological professional, interpretation of the data is dubious. GIS software allows the geologist to view remote digital data in combination with information which was collected on the ground and subsequently captured into digital format. However, for the mine geologist, GIS software is no longer suitable as it does not represent true three-dimensional objects with independent variables in all three coordinate axes. At this level, a multi-dimensional modelling package is needed to represent the orebody in space.

3D Geological modelling

The dependence of a mining operation on an accurate 3D geological model is growing for all scales of operations, from small quarries to large open pit and underground mines. This trend can be attributed to an increasing demand for efficiency in mining with managers expecting accurate information on a regular basis. All requests relating to the resource or reserve ultimately lead back to the geological model on which planning and production activities are based. But how well do these models represent the geology of the orebody?

Geological modelling software makes use of spatial information, that is x, y, z coordinate data to construct 3D models which represent the geometry of an orebody. Internal geometrical features such as mineral zonation and grade distribution are also represented in these models, as are external influences such as cross-cutting dykes, country rock effects (e.g. metamorphism and alteration), structural elements and xenoliths. The coordinate data may be lithological intersects measured from surveyed drillhole core, or it may be surface and underground geological contacts mapped on paper and then captured into digital format. Topocadastral survey data are also used. This information can be imported into a system as point or vector data which is then 'connected' to create data objects known as geological 'solids' or 'wireframes' (Figure 1). The way in which the connections are made can be controlled by the user up to a point, but the actual creation of the solid is automatic and makes use of a mathematical algorithm which triangulates between x, y, z points to create a triangulated irregular network (TIN), see Figure 1. According to Barchi *et al.* (1990), the geologist should retain a certain degree of control over the creation of the model and apply additional knowledge not necessarily contained in the data.

Coordinate data may also be sample information which, in addition to spatial x, y, z data, must also contain additional numerical information such as a sample or identification number, assay results, geotechnical parameters and so on. This information is supported in a modelling system as point data for the purposes of contouring, but more importantly, the data can be used to determine a semi-variogram of a particular variable (e.g. Au ppb) and then interpolated by a variety of techniques such as inverse distance and kriging to estimate the grade distribution within an orebody. Such techniques can also be applied to geotechnical and geohydrological data to construct multi-dimensional domain models.

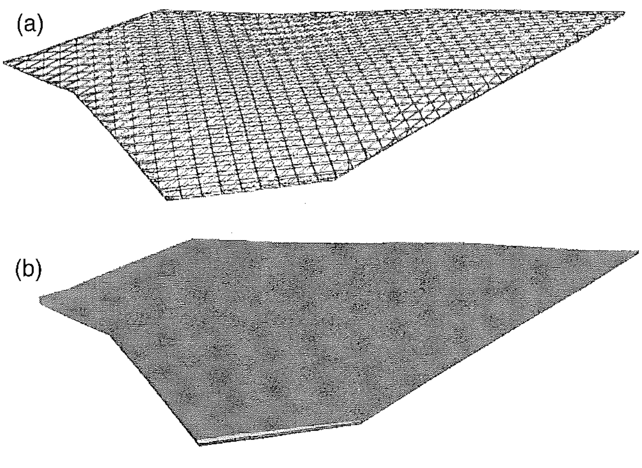

Figure 1. (a) The geometry of a TIN, and (b) a rendered 3D image of a geological solid

Discussion

Combining geometrical and numerical data in a 3D modelling package serves a critical function during the evaluation and feasibility stage of an ore deposit, as well as once the mine is brought into production. During production, the mine planning staff can schedule or sequence mining operations on a time period basis, e.g. months or years, and the production staff can predict the tonnage and grade of ore to be mined over the same time periods. This places the geology department, custodians of the 3D geological and grade models for a mine, firmly within the mining value chain (Figure 2) because without updated accurate geological information, the mining operation cannot function efficiently.

Conclusions

Negative perceptions regarding the accuracy of computer generated 3D geological models are unfounded and typically result from the incorrect use of software applications. 3D modelling software has been used successfully to model a wide variety of orebody types including kimberlite pipes, thin tabular reef deposits, porphyries, archaean gold-lode deposits, heavy mineral sand deposits and coal seams to mention only a few. Provided that geological professionals do not lose sight of the importance of accurate data capture and detailed geological interpretation, the use of multi-dimensional modelling software should complement traditional mapping techniques and improve the professional output of geologists in the mining industry.

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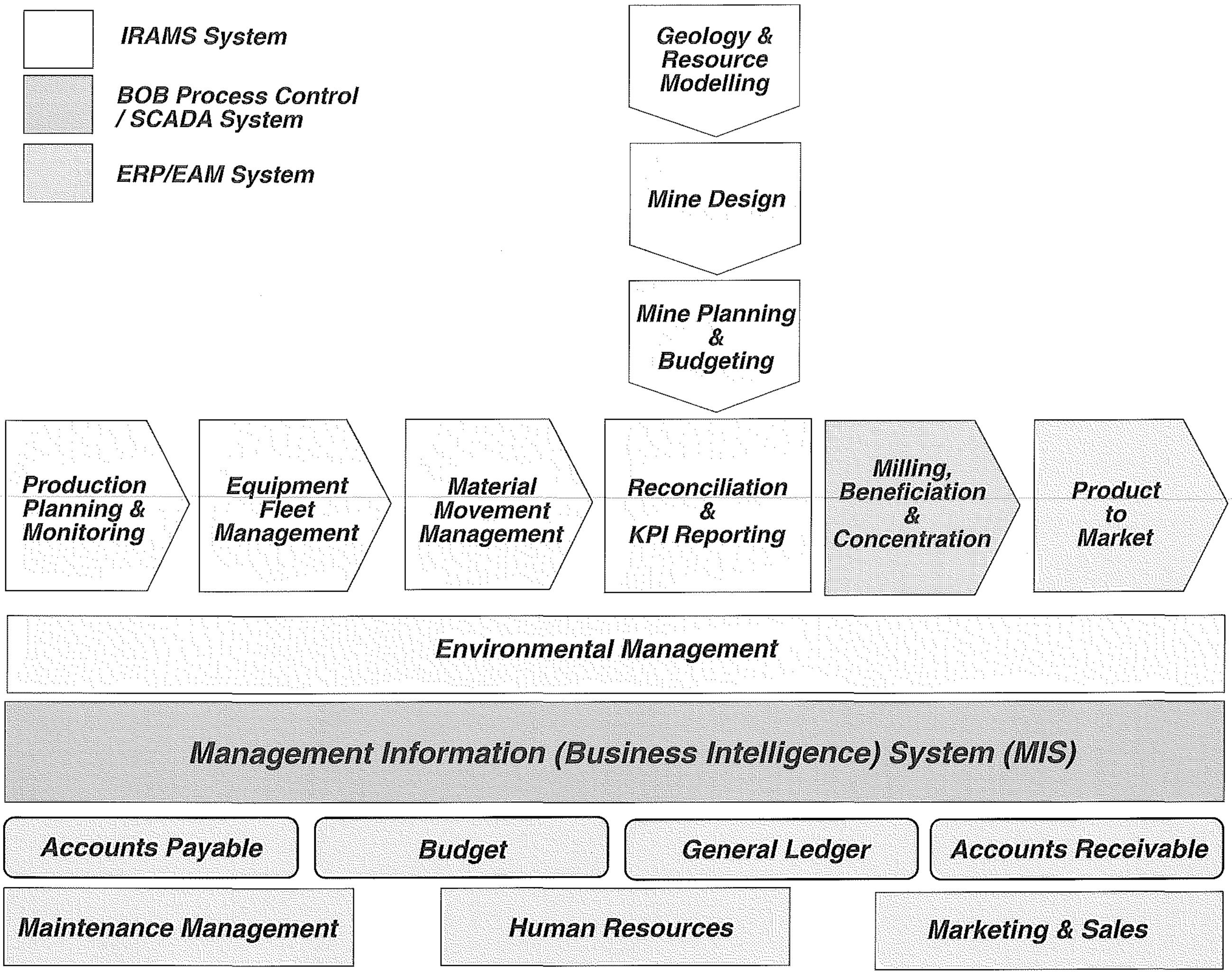

Figure 2. The mining value chain (after Jones, 2001)