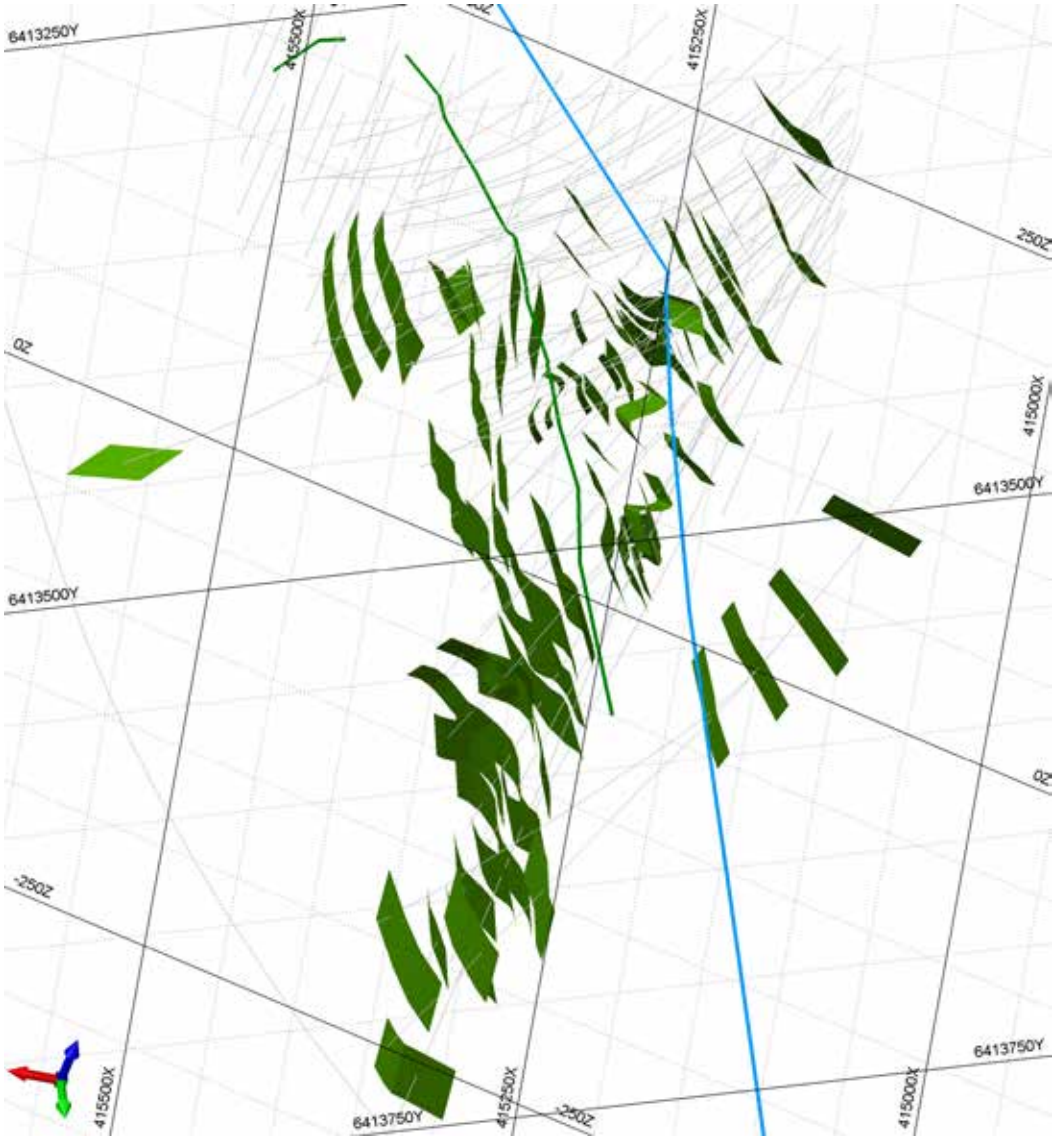
MAPPING AND STRUCTURAL GEOLOGY IN MINERAL EXPLORATION

Where theory hits the fan

Rod Holcombe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Frontispiece: *Top: Exposed fold hinge, Cape Liptrap, Victoria, Australia. Bottom: Array of 3D form surfaces to bedding constructed from dill core data from a gold prospect in the Cobar region, Australia*

Contents

Acknowledgements

I owe a great deal to a large number of people who have been influential in my development as a structural geologist. Among these I hold Bruce Hobbs, Paul Williams, Ron Vernon, and Tim Hopwood in high regard for lighting the fire in my University years; Nick Oliver, Paul Pearson, Terry Harbort, Renate Sliwa, Rick Gordon, Mike Williams, Tim Coughlin, Chris Stephens, and (particularly) Timothy Little for stoking the coals during my academic and teaching career; and Dave Horton, Mike Schmulian, Philip Newton, Nick Fox, Cees Swaager, Cameron Cairns, George Schroer, Stuart Smith, and all the other exploration people who, over the past twenty years or so, have given me the luxury of seeing more rocks and structures in more exotic locations than I had ever dreamed I would see. In particular, Stuart Smith was, perhaps unknowingly, instrumental in starting me to think about writing this text, initially as a manual for an in-house mapping course in Thailand.

As always, I am indebted to Nick Oliver for trying to curb my enthusiasm with his enthusiasm, and particularly helping me to not be one-eyed about breccia. And to Rick Valenta for improving the cover design.

Preface

The best geologist is the one who has seen the most rocks
Herbert Harold Read
... and ain't it the truth!

This manual is aimed at young practising professional geologists in the minerals industry, particularly those working in deformed and folded terranes. The assumption is made that the reader already has a geological background and this manual is intended as a way to focus and revise that background. It has been arranged somewhat in reverse order to a conventional text in that the early sections explain how and when to apply particular techniques in the context of fieldwork and mapping, and later sections explain the theory behind those techniques.

It is also a highly personal, and perhaps idiosyncratic, manual. It is based on my own thoughts and philosophy about what it takes to be a top tier professional geologist. Thoughts such as:

- You never stop learning. In a reflection of the H.H. Read statement shown above, I believe that at least one third of the training of a geologist is experience, thus putting young professionals at a distinct early-career disadvantage. The initial drive for writing the manual was from repeatedly seeing the same mistakes made by young professional geologists, while I knew that in thirty years' time they would probably not make that same mistake. This manual is heavily based on my own experience (be that a good or a bad thing) with the thought that if I can articulate my experience, it may speed up the acquisition of experience by the reader.
- Orebodies are anomalies, and the structures that control them are commonly also anomalous. The regional context may be a systematic textbook structure, but the local mineral occurrence is more often than not controlled by non-systematic structures that rarely fit any textbook models. I use the term *accommodation structures* for anomalous structures that have allowed a deformation to proceed by departing from the dominant mode of behaviour - brittle or ductile. Some accommodation structures, such as gash veins, which are brittle structures accommodating a ductile shear, are well understood and systematic, but many other accommodation structures depart markedly from textbook behaviour. In particular, mineralisation in orogenic belts is commonly associated with non-systematic faults and fractures associated with ductile folding. Such structures can appear to violate many of the characteristics normally associated with faults (such as strong curvature and rapid changes in slip and slip sense) and it is important to recognise them for what they are and understand how to deal with them.
- Theory is as important to a professional geologist as it is to an academic. A good geologist should be able to interpret previously unseen or anomalous structures on the basis of a good theoretical background. This viewpoint is strongly influenced on my own experience in which more than thirty years of academic teaching and applied and theoretical research preceded a full-time structural consulting career. So I put great store in the belief that every outcrop should be understood at both a practical and a theoretical level in order to achieve a high level of confidence in any interpretation. Thus throughout this manual I have tried to integrates the description and treatment of structures with the underlying theory.
- A field geologist should assess every outcrop or core sample he or she sees within the context of a continuously developing broad-scale model. Does this outcrop fit the context of the last outcrop; what do I expect at the next outcrop; and what do I see here that challenges my view of the broad-scale model? Associated with this is my belief that the concept of multiple working hypotheses is a fine ideal, rarely practiced. It is not what most geologists do. Most geologists have a dominant prevailing model (working hypothesis) – and that is no bad thing, provided it is approached with an open mind and a willingness to modify or change a model based on new observations. Awareness and continuous model testing is the key activity that avoids missing that critical outcrop that changes everything. The downside is that in some cultures (both national and corporate) junior geologists feel unable to question prevailing models devised by senior geologists. Nonetheless, for them to develop into a top class geologist they must make the effort to continually test the model in their own day-to-day observations.
- Finally, I liken a geologist to a GP doctor. Both look at surface symptoms and, prior to undertaking invasive actions, have to come to a diagnosis that may be critical. The range of solutions is enormous, the symptoms for any solution can vary widely; and knowledge of those symptoms and that solution may only have occupied a few hours during the years of university training. Most geologists' training is considerably shorter than that of a GP. No wonder then that most professional industry geologists are poorly equipped to recognise and respond to unusual geology, and it is also understandable that they may have forgotten some very basic aspects that may have been covered only in their first few weeks of a Geology degree. It is one reason why some chapters of this manual dwell at such length on some basic aspects. For example, I have run into enough examples of geologists being unaware of the relationship between topography and outcrop pattern to realise the need to cover this most basic of topics in some detail.

This manual does not replace an introductory structural geology textbook. Nor does it cover all aspects of structural geology to the same level. It dwells on those aspects with which I have most experience in (such as ductile fabrics, folds, and shear zones), at the expense of other aspects (such as some faults and other semi-brittle structures such as most veins). Even then, it concentrates on those aspects

of structure in which I have seen mistakes made by exploration and mining geologists working in specific types of terranes, or in which techniques can be applied that are not in the usual armoury of an industry geologist. It also does not proceed into advanced structural topics such as the geometrical analysis of terranes that have undergone complex superposed folding . Although these are mentioned, it is such terranes that really does require bringing a specialist structural geologist into the exploration team.

This manual arose out of a series of in-house mapping courses that I delivered in Thailand some years ago. The main purpose of the course was two-fold:

1. to encourage exploration geologists (some quite senior) doing regional 1:50000 scale reconnaissance mapping to get beyond the simple data acquisition stage of just recording rock-types and measuring bedding, etc., but to develop that data into a regional geological and structural model that could be used as a basis for exploration. That is, to push them beyond their corporate comfort zone into the somewhat risky realm of interpretation.
2. to give highly inexperienced young geologists with poor background training in outcrop procedures, and pit mapping.

Consequently the first chapter deals with aspects of mapping at all scales. Likewise, the second chapter deals with the purely technical aspects of field, pit, and mine geology. I apologise to more experienced geologists that some of the sections in this chapter are very elementary.

Chapter 3 is mainly a basic primer on the criteria for determining stratigraphic facing (younging) in the field.

Chapter 4 provides a basic overview of the structures found in rocks. Its main purpose is to allow a fast revision of the gamut of basic structures as well as to provide an outline of the terminology and concepts that I use within the rest of the text.

Chapter 5 deals with the problem of recognising and interpreting breccia bodies, and includes a number of specific case histories.

Chapter 6 includes all aspects of structures in 3D, starting with contacts and topography before moving into 2D cross-sections ,and finally aspects of 3D modelling.

Chapter 7 describes the problematic aspects of folded and cleaved rocks, and how to extract maximum map an structural information from an outcrop.

Chapter 8 deals with shear zones from a field perspective, ranging from low strain shear zones to mylonite. (Theoretical and more advanced aspects of shear zones are dealt with in Chapter 10).

Chapter 9 deals with extracting structural data from oriented drillcore and providing quality control on the data. This chapter is extracted from my on-line manual on Oriented Core Procedures at: http://www.hcovglobal.com/#!downloads/lf947.

Chapter 10 provides the theoretical background for many aspects of deformation underpinning the material discussed in the manual. It includes an outline of the principles of deformation and rock flow, folding, shear zones, and fracturing.

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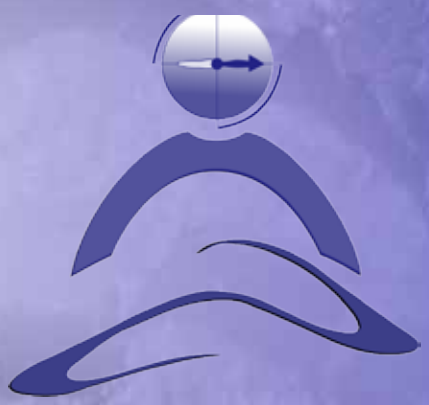

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