GOLDEN STAR   EXPLORATION

STANDARD PROCEDURES FOR

ORIENTED CORE MEASUREMENT

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1.0 INTRODUCTION

This procedure is designed to ensure valuable geological information can be derived from oriented core measurement of geological domains to unravel the tectonic evolutionary history when drilling diamond core within the Golden Star Exploration Group. The task description and procedural summary of field Mapping and oriented core analysis is divided into different stages. But this procedure will concentrates mainly on structures found in core and how to measure these structures to place them in their geological context so they can be used for models generation and provide parameters for resource estimation.

1.1 OBJECTIVES

The objectives of this Standard Procedure are to:

- Define the standards to be applied for the planning, measuring, plottting, interpretation and analysis of structures in real space and in time,
- Identify the responsibilities for the person(s) performing the activities,
- Observe and interpret the distribution of lithologies and structures in core
- 3D visualization of structures in complex geometries in core
- Development of skills in determining overprinting relationships from drill core
- Stereographic plot of structural dataset.

This ability is critical both in mine and exploration environment which leads to ore targeting.

2.0 GEOLOGICAL STRUCTURES IN CORE

2.1 FOLDS

Fold anatomy: A quick reminder of the nuts and bolts. Axial surfaces need not be planar; hinge lines need not be straight!! Hinge lines are the location of maximum curvature. Fold axes are (imaginary) lines that can describe the fold if moved parallel to it. 1st and 2nd order enveloping surfaces can be used on parasitic folds to simplify complex fold structures; this is also useful with refolded folds.

Folds and fold sets can be classified according to:

- Shape: angular, rounded, box folds, kink-folds, etc.
- Geometry
- Asymmetry
- Attitude – orientation
- Tightness
- Amplitudes, wavelength in core

2.1.1 Vergence in folds

A large structure may not be seen in one small core. Small scale structures allow geologists to work out basic aspects of the geometry.

- Vergence refers to the asymmetry of structures on the limbs of major folds.
- Vergence is used to identify the direction in which the next major closure is to be expected. Thus, major fold closures can be approximately mapped out even if the main closure is never observed.
- Always look (and think) down-plunge when establishing vergence.

2.1.1.1To identify vergence we can use:

- The shape of parasitic folds (Z, S or M folds). The arrow indicates the 'sence of overturning', and is the direction of vergence. Folds with M shape have 'neutral vergence', they often occur in hinge zones.
- Cleavage – bedding angles. Mentally rotate younger towards older (S1 to S0, or S2 to S1)
  - For an upright fold we identify vergence as the direction (perpendicular to the axial plane) in which one would expect the next antiformal closure.

- Recumbent and vertical folds cannot be described as antiforms and synforms.
- For recumbent folds, vergence can be defined as the direction towards the next down closure folds are best described having clockwise or anticlockwise 'sense of symmetry' of being 'S' or 'Z' folds.

If minor folds have a 'neutral ' vergence (M-shaped) one would expect to be near or in the hinge zone of a major fold closure.

2.1.1.2 Use of vergence symbols on section maps

- In areas where fold axes plunge relatively steepy (and do not change plunge direction in 'saddle' structures) the best symbols to use are the Z and S symbols. Use these always in conjunction with a fold axis plunge symbol:
- In areas with shallow plunging folds and/or steep slopes folds can change from S to Z shown on the left:

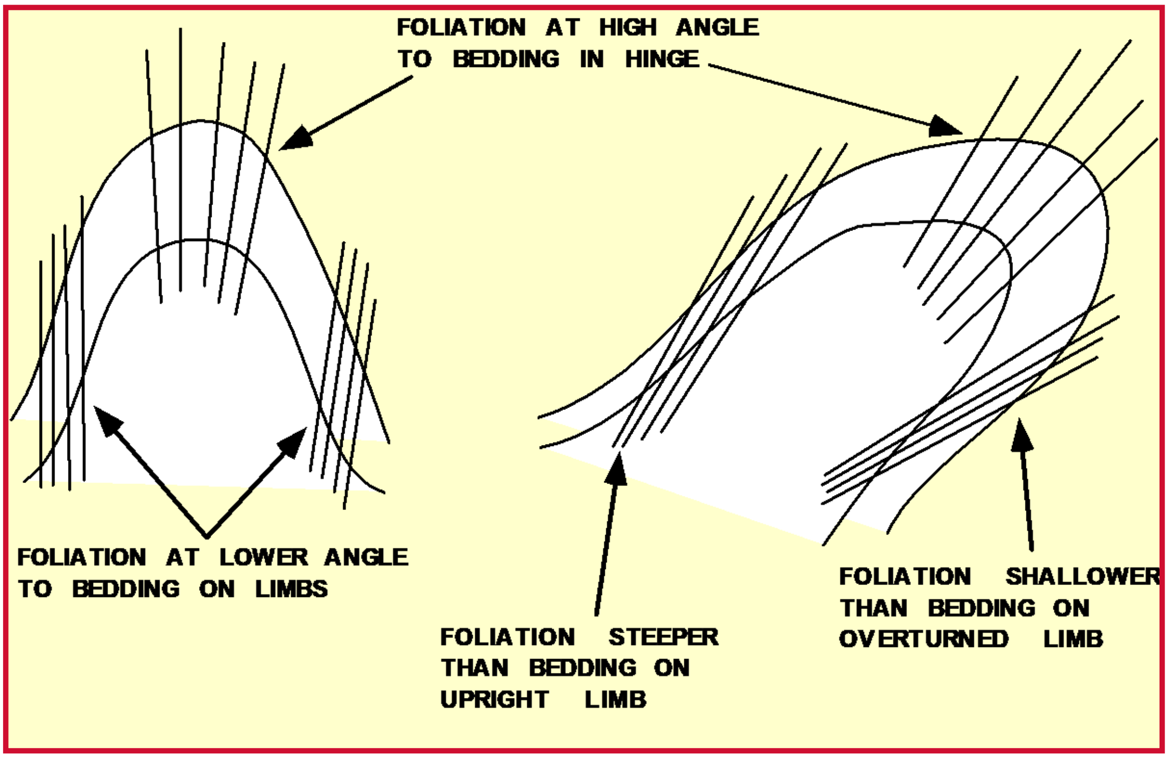
2.1.2 WHAT TO MEASURE & HOW TO DESCRIBE FOLDS FOR STRUCTURAL ANALYSIS IN ORIENTED DRILL CORE

With the aim of structural analysis of the deposit, the following data on folds should, ideally, be collected in the core by GSE Geologist logging core:

- Strike\dip direction & dip of axial plane. Measure axial planar cleavage, preferably in the hinge zone, where the effects of cleavage refraction are minimal.
- Plunge & plunge direction of fold axis. Measure intersection lineation of bedding\foliation and axial planar cleavage (but make sure that the cleavage is axial planar to the fold and not of another generation)
- Establish the vergence if folds are asymmetric (and think where the next antiformal\synform closure is expected). Look down the plunge direction of the fold while doing this.
- Establish facing. One needs to observe stratigraphic younging.
- Fold classification: draw a sketch of the fold profile.
- Tightness: measure the strike & dip of the two limbs.
- Axial planar cleavage: describe. Specific mineralogy.

Other things to look for:

- Cylindricity: measure a few fold axes of a set of folds: are they parallel?
- Is there cleavage refraction?
- Are the fold axes straight or curvilinear? Sheath folds? Or refolding?
- Are lineations on bedding parallel to the fold axis or not? If not, think refolding!



2.2 FOLIATIONS

These include cleavages, shcistosities, differentiated compositional layering, mylonitic foliation.

2.2.1 Foliation Forming Processes

Foliations are a result of permanent rock deformation. The major controlling factors associated with the development of foliations are:

- Grain size
- Rock composition
- The orientation and magnitude of strain
- Metamorphic grade (temperature, lithostatic and fluids pressures)

- Fluid composition

All foliations and cleavages in core needs to be documented

2.3 FAULTS

Faults are brittle to semi-brittle fracture discontinuities in a rock along which significant movement has taken place. The geometry faults in drill core must be measured

2.4 JOINTS AND VEINS

Joints are relatively continuous planar fractures along which there is little or no appreciable displacement. They can occur on a range of scales from the microscopic to hundreds of meters in length and spacing. Joints often display a systematic arrangement of one or more preferred orientations or joint sets, which sub-divide the rock mass into a series of sometimes remarkably regular three dimensional 'jigsaw' pieces.

2.5 Veins

Veins form when minerals precipitate within a fracture. They indicate conditions in which fluid pressure exceeded the rock strength, if only for a short time, either re-activating or initiating the fracture into which it then precipitated minerals. Veins can form in extensional or shear related joints but not restricted to these features. In fact, vein minerals may precipitate into any dilational volume within a rock (eg. Fault jogs and fold hinges)

In shear zones an en-echelon array of tension gashes (extensional veins) may form normal to the direction of least principal stress. Continued shearing can rotate older formed veins or sections of veins forming a complex pattern of overprinting, variably oriented sygmoidal veins which is a reliable shear sense indicatior.

3.0 CORE ORIENTATION

3.1 Procedures

Orientation of geological structures can be determined from drill core with the aid of orientation line. The orientation of the core before it was removed from the ground must be known. The down-hole survey data provides the dip and azimuth-direction of the axis of the core, but additional information is required to fully orientate the cylinder of core. Several mechanical devices are available to determine the bottom of the core in inclined drill holes, but GSE uses Ezy-Mark/spearing mark and OriShoot system (which includes brown spear). For GSE the orientation marks are usually done after completing each 6m runs (HQ normally 3m length).

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3.1.2Potential errors at the drilling stage:

- Bending or distortion of the spear rod. Both the supervising geologist and the driller should inspect the spear rod before any new drill hole. Roll the rod on a flat surface to detect distortion.
- Dropping the spear too fast onto the rock, such that the spear either bounces off the wall of the core barrel or impacts too fast onto the rock and produces several impact marks. Ideally the spear should just touch the rock and then be withdrawn. There should be no impact marks at all.

3.2 Core Orientation Line

Once core with an orientation mark (spot) has been extracted, the next step is to draw a line marking the bottom of the core. This line is marked with arrows showing the down-hole sense, and **preferably should be in a different colour** to that used to mark the cutting line of the core. (Note also that the when core is split for assay, the orientation line should always be on the half that is left in the box). The lines extend as far along the core as it is possible to match broken core segments up. In areas where it is important to obtain orientation data the core may have to be glued to produce a coherent interval. Core breaks should be assessed by GSE logging Geologist as some apparently good contacts can be the result of grinding induced during drilling.

At least one down-hole arrow should occur on every segment of the core. If the core cannot be oriented then do not record an orientation line. No information is better than wrong information.

Errors can arise with the matching of the line across broken core segments. Note that it is very easy at this stage for small rotation errors to creep in and these affect the accuracy of the measurements. For this reason it is best if this part of the process is done under very controlled supervision by GSE geologist. The core is laid out on a rack of sufficient length to hold at least three or four complete runs of core. Not only should the bottom line be extrapolated along each run of core, it should also, where possible, be matched with the adjacent runs. GSE core racks are best and made of angle-iron of a size such that the edge of the steel frame is exactly at the half-height of the core. The core is then lined up with the bottom line lying along this edge of the angle-iron. Once a full length of core has been lined up correctly then the angle-iron provides a straight-edge to control the drawing of the line. Other racks are made using lengths of drill rod welded together, but these do not provide the useful straight-edge of the angle-iron..

For Golden Star Exploration:

- *Core with red orientation 'bottom' line and yellow* cutting line
- *Core orientation frame made from angle iron and long enough to hold multiple core runs at one time*

Errors can also arise if the straight edge used to mark the line is too short. In these instances it becomes too easy to accidently draw the line slightly obliquely to the core axis.

3.2.1 Unoriented drillcore

During core drilling, runs of core (commonly ~ 3 metres long) are extracted from a core barrel at a time. The extraction process rotates the core randomly, so that once the core is laid out in core boxes its original orientation is lost. GSE do not accept unoriented drill core.

NOTE: GSE Geologists must ensure that *driller's involvement with core orientation should end with the identification of the bottom mark. It is poor practice to allow the driller to mark-up the core as this will generally be done by the driller's offsider, and neither may have a vested interest in the accuracy of the mark, or knowledge of how important it is for precision.*

3.2.2 Potential Erros and Control

Structural measurements derived from oriented drill core have a range of potential error sources that must be continually monitored and minimised in any large-scale, long-term drilling program.

Errors can occur at several stages in the orientation process:

- The orientation mark might be imprecise or incorrect. This is a problem with the driller's technique and expertise. For example with a 'spear' tool the tip of the tool should just touch the top of the core run and be lowered slowly, so as not to bounce the spear off the bottom of the hole. The GSE shift geologists need to monitor the orientation process and impress on the driller the need for precision.
- The orientation mark may be translated imprecisely onto the core by the GSE logging geologist or technician. Core sections in broken core may be inaccurately aligned when aligning the bottom mark along the core.

- Statistical errors can arise from bias in the choice of which features to measure, or even from drill holes that are inappropriately oriented relative to the feature of interest

3.3 MEASUREMENT AND DESCRIPTION OF STRUCTURAL FEATURES

There are two main methods by which geologist can measure structures in oriented drill-core. The first involves the use of a "rocket launcher" or core frame. Golden Star Exploration uses rocket launcher. This method allows GSE geologist to place the core in the exact orientation it was before drilling. The geological structures are then measured in real space and in time, with a compass. GSE procedures also consider measuring angles of a fabric to core axis (alpha) for computations.

The Rocket Launcher should be non magnetic.

Structures in drill core are grouped into planar and linear fabrics. Planar fabric includes bedding, foliations, cleavages, veins, joints and faults. Linear structures include fold axes (hinges), intersection lineations, stretching lineations and slickenlines, fold hinges, and elongate boudins. All these structures can be measured using either compass in real space. This measurement in the core must be taken in strike and dip or dip and dip direction. For standardization GSE records all its measurements in dip/dip direction.

Direct entry of recording structural data from oriented diamond drill-core into a computer programme (aQuire) is emphasized. Besides the structural measurements, other critical data that should be recorded such as; down-hole depth of the structure

- structural domain the structure occurs in.
- lithology that hosts the structure.
- type of structure.
- paragenetic stage (e.g. 1, 2, 3 etc) of the structure and minerals in it or associated with it.
- minerals that fill the structure or occur in its selvage.
- shear-sense of the structure if available (i.e. reverse, normal, sinistral, dextral or oblique, sinistral-reverse).
- Vein types (e.g. for Wassa, Syn D_1 Extensional quartz vein etc…..)

4.0 PLOTTING ON SECTIONS AND INTERPRETATIONS

One of the goals of a geologist is to understand the three dimensional geometry of deformed rocks. The geometry of structures below the surface and the projection of those features unto a map are very critical in exploration activities. Cross sections are 2D educated guesses at the geology along a plane different from the surface of the earth. For the purpose of doubt his plane must always be vertical.

- Determine the line along which you are going to draw the section (preferably along the azimuth of drilling). This section must include the hole whose measurement has been taken.
- In section view plot dip of planar structures and indicate direction of dip for each structural features at particular depth along the drill hole and plot trend/plunge direction of linear features

- Mark lithological contacts and boundaries on the section.
- Draw structures (faults, folds, cleavages etc….) and the lithologic units on the section

- Extend structures and lithologic units, if sufficient information is present to do so. This is the most subjective part of the process and multiple interpretations are possible. You may want to complete several alternative interpretations. The most important thing is to keep in mind that your section should be geologically, geometrically and physically reasonable.

- Finally, finish the section by drawing in the traces of the axial surfaces of anticlines and synclines, measuring offsets across the faults, and determining the stratigraphic thicknesses of the units. Colouring the section is also a good idea

- Plotted data can be analyzed on stereonet for solving problems