A unified approach to measuring structures in orientated drill core

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Abstract

A unified system of collecting structural data from drill core is proposed. The system encompasses planes and planar fabrics, lineations, fold hinges and hinge surfaces, faults and shear zones, vorticity vectors, shear directions and shear senses. The system is based on standard measurements of angles in the reference frame of the core (α and β angles), which are easily carried out by means of core protractors or templates. The methods for dealing with folds and kinematic analysis of shear zones have not been described previously, but they follow logically from the standard methods for dealing with planes and lines.

Diamond drill core is arguably the most important source of data for mineral exploration and development at the deposit scale. Since hydrothermal mineral deposits typically have strong structural controls, analysis of structures from orientated drill core is critical for the successful utilisation of such resources, as well as for understanding the geology of deposits. Many tens of km of drill core may be acquired for a single deposit during exploration before any ore is mined, and further drilling almost invariably occurs to investigate extensions of known mineralization once mining has started. An efficient method of structural data collection from drill core is essential to deal with this volume of data. Standardisation of the approach in production logging environments is a prerequisite for digital data capture, management and integration, improves the ability to identify discrepancies, and facilitates training of personnel. Structural analysis from drill core may be even more vital in future as exploration moves from well-exposed terrains into target areas obscured under deep cover.

Once drill core has been analysed, mineralised sections of the core are typically cut: half of the core is sent for assay. The remainder of the core is stored, commonly in an exposed manner where it can rapidly deteriorate, especially if it contains sulphides. Such core will need to be re-analysed if the initial structural assessment is incomplete. This step is much more difficult from half core, more so if it is weathered. Structural data collection from drill core therefore needs to be thorough as well as efficient. A comprehensive structural analysis from the outset allows alternative ideas for deposit genesis to be tested as the deposit is mined, and has major benefits for resource estimation.

Core is orientated by a variety of techniques during drilling (e.g. Marjoribanks 2009), which generally result in a point being marked at the lowest part of the core – the bottom-of-core (BOC) mark. The BOC mark is made at intervals (typically after each core run of a few m), and intervening core is orientated by aligning adjacent BOC marks so that a continuous line can be marked along the bottom of the core – the orientation ("ori" in typical Australian vernacular) line. Arrows are commonly marked on the orientation line to indicate the down-hole direction. Fragmentation of the core may degrade the quality of orientation, and other factors may also contribute to poor or erroneous core orientation (e.g. Davis & Cowan 2012). If limited drill core is available it may be appropriate to mark an unconfirmed orientation line in a different colour and record structural data collected from these intervals as unconfirmed. The minerals industry does not typically use borehole imaging techniques (cf. Paulsen *et al.* 2002), so that core from vertical holes is difficult to orientate; however, almost all exploration holes are inclined. The BOC mark and line is the basis of all techniques used in this paper.

There are several methods of collecting structural data from orientated drill core (e.g. Marjoribanks 2009). Probably those most widely employed use various devices (template, rat-trap, core protractor: Fig. 1) that specify the orientation of structures by measuring angles relative to the core axis and the BOC line. Subsequently these measurements must be combined with data from the down hole survey of hole orientation to retrieve the true orientation of structures. Because of the universal tendency of drillholes to deviate, accurate survey data, specific for the depth of the measurement, must be used. The aim of this paper is to propose a systematic and unified system of collecting a comprehensive suite of structural data from orientated drill cores using angles measured in the core frame of reference. The basic methods for planes and lines are described first to show how new methods dealing with folds and shear zones can be developed logically from them. The paper does not address the merits of various techniques of measuring structures in cores (described in Vearncombe and Vearncombe 1998), problems of core orientation, or procedures for reorientation of structures to a geographic frame of reference (e.g. Holcombe 2013; Stanley and Hooper, 2003)

α-β Method – Planes and Planar Fabrics

The α-β method for measuring planar features is in widespread use (e.g. Vearncombe and Vearncombe 1998; Marjoribanks 2009). The angles α and β characterise the orientation of a planar feature. α is defined as the angle between a line parallel to the length of the core (the core axis) and the plane (Fig. 2). β is the angle measured clockwise looking down core from the BOC line to the down-core axis of the ellipse formed by the intersection of the plane and the core (Fig. 2). The whole process of extracting a piece of core from a core tray, measuring α and β, and returning the core to the tray can be carried out in less than a minute, and is not subject to errors due to magnetic minerals that affect compasses.

β and γ Methods – Lineations

Lineations can be measured in two ways, both requiring the lineation to be interpolated through the centre of the plane in which it lies. A γ measurement is similar to measuring the pitch of a lineation in a plane (Fig. 3), but the measurement is made with reference to the down-core end (long axis) of the plane ellipse (cf. Holcombe 2013; γ is defined differently in some literature e.g. Laing 1977; Vearncombe & Vearncombe 1998, but the Holcombe definition is used here). Alternatively, the location of the lineation on the ellipse defined by the plane in which it lies can be used to define the lineation orientation (Fig. 4). The point where the lineation, interpolated through the centre of the ellipse, intersects the circumference of the ellipse can be measured by a β angle (clockwise looking downhole from the BOC mark) (Marjoribanks 2009), which is referred to as δ by Vearncombe & Vearncombe (1998). This measurement is distinguished here by the suffix L (βL) to distinguish it from the simple β measurement for a plane. This notation is introduced to avoid any possible confusion with other Greek symbols, and to maintain consistency with the following methods. The βL measurement can be combined with the α and β measurements of the pane in which the lineation lies, and the downhole survey data, to solve for the true orientation of the lineation.

There are two advantages to this method of measuring lineations: firstly, no additional equipment is needed beyond the template/rat-trap/core protractor, compared to the γ measurement that additionally requires a conventional protractor. Secondly, as shown below, the β method can be extended to other lines (fold hinges, the vorticity vector), making it part of a unified way to collect structural measurements from core.

Folds

Folds can have a complex expression on the cylindrical surface of a core, but typically they will consist of a closed shape formed by the intersection of the core and the folded surface (Fig. 5). A method for core analysis is required that can measure the orientation of both the hinge and the hinge surface (axial plane). The hinge surface is simply dealt with by the α- β method for planes. Because the hinge surface may not have a direct physical expression in a fold, it is useful to mark the surface on the core to measure it accurately (Fig. 5b).

Hinges pose a more difficult problem than lineations, because the hinge surface in which they lie is generally not exposed in the same way that lineations are seen on a foliation surface, and a hinge is commonly a discrete line that does not pass through the centre of the core. This problem was recognised by Scott & Berry (2004), who proposed a method that uses three angles measured from a transparent template to define the orientation of a fold hinge.

Here, a new method to measure fold hinges is proposed that uses β angles, and a single length measurement on the core (Fig. 6). βU is defined as the β measurement of the up-hole intercept (U) of the fold hinge with the core. βD is similar for the down-hole intercept (D). The distance UD is defined as the distance between U and D measured parallel to the core axis (Fig. 6). These measurements can be combined to solve for the orientation of the hinge. Advantages of this method are that it can be executed with a template/rat-trap/core protractor and a simple ruler, that it extends the unified method developed here, and that it is simpler than the Scott and Berry (2004) method that requires a special template. The method can be applied to any cylindrical fold defined by a single layer, but disharmonic folds, and refold structures on the scale of the core, are difficult to deal with.

Shear Zones

Structural analysis of shear zones requires measurements of foliations, lineation, shear plane, and shear direction in mylonites, and determination of shear sense (Fig. 7). Foliations and shear planes are readily measured using the α-β method, and lineations by the βL method outlined above. The shear direction was commonly taken as approximately parallel to the stretching direction as represented by the lineation, but particularly following the work of Tikoff and co-workers (e.g. Tikoff & Fossen 1993, Tikoff & Teyssier 1994), it has been realised that this approximation is not generally true, and that the relation between the shear direction and the lineation is a function of the relative amounts of pure and simple shear, or the vorticity number (Fig. 7). Therefore a complete analysis of shear zones requires measurement of the shear direction independently from the lineation.

The key to making a comprehensive kinematic analysis of shear zones in core is the concept of the vorticity vector. The vorticity vector is the axis about which internal rotation occurs in a shear zone (e.g. Means *et al.* 1980; Xypolias 2010), which is perpendicular to the shear direction within the shear plane (Fig. 7). The vorticity vector can be identified in a shear zone as the direction perpendicular to the plane containing the maximum asymmetry of shear sense indicators, such as winged porphyroclasts, asymmetric boudins, quarter structures, pressure fringes and shadows and S-C fabrics (Fig. 8). This plane is also referred to as the Shear Sense Observation Plane, the Vorticity Profile Plane, or the Vorticity Normal Section (Robin & Cruden 1994; Jiang and Williams 1998).

Here core analysis has a significant advantage over outcrop geology. A single piece of core intersecting a shear zone generally affords a complete view of the shear plane through 360°. It is therefore possible to identify the vorticity vector relatively accurately compared to many outcrop situations where this level of exposure does not exist. The vorticity vector can be identified as a point on the core surface within the shear plane, and it can be measured by a single β measurement (βV: Fig. 9). This allows the shear direction to be calculated as the normal to the vorticity vector and within the shear plane.

S-C and S-C' fabrics offer an alternative method for shear direction determination. The intersection between S and C or S and C' surfaces is perpendicular to the shear direction (Fig. 10). These surfaces can be measured by the α-β method, from which it is possible to calculate the shear direction (SD), which lies in the C or C' plane perpendicular to the intersection of the planes (Fig. 9).

Shear sense can be specified in several ways, depending on the orientation of the shear zones and drill core, and user preference. The ideal situation is when the true orientation of the shear plane and shear direction is known. In this case, the shear sense can be classified by qualitative kinematics i.e. dip slip (normal, reverse), strike slip (dextral, sinistral), or oblique slip (dextral normal etc.). This determination can commonly be made by holding the core in the approximate orientation that it was drilled, and making a visual inspection.

However, in cases where shear planes are either approximately horizontal or vertical, it becomes difficult to distinguish dextral from sinistral and reverse from normal without accurate reorientation of the core, because the dip direction is uncertain. A second method can deal with these situations. The uphole side of a shear zone can be unambiguously identified for all shear planes except those through the core axis (Fig. 11). The shear sense can then be recorded as, for example: "The uphole side has moved to the north" etc. Subsequently this record can be interpreted in kinematic terms when the data is plotted on a stereonet: the uphole side is readily distinguished on a stereoplot as the area that does not contain the core axis (Fig. 11). For planes that are parallel to the core axis, it is usually possible to identify the two halves of a core in a third way: geographically. Thus it is possible to state, for example: "the east side of the shear zone has moved north" etc. These comments on determining shear sense also apply to faults.

In all three cases above, an alternative to describing movement directions is to specify the rotation sense of the vorticity vector (clockwise or anticlockwise). It is essential to view the vorticity vector in consistent direction: the convention of a downplunge direction is recommended. However, this direction can be difficult to establish for shear planes that are approximately horizontal. In such cases a downhole direction can be more readily established. The sense of rotation of the vorticity vector can be simpler to record than the shear sense as specified by movement directions.

Half Core

Core is commonly cut relatively soon after drilling for assaying. In some cases the half of the core with the orientation mark is regrettably sent for assay, in which case it is only possible to use the remaining half if some sort of reconstruction can be attempted from the adjacent core. Even if the orientation mark is preserved, however, it may not be possible to use the α-β method, because one or both ends of the ellipse formed by the intersection of the plane and the core are not preserved. A method that uses two linear measurements and one angle, on core of a specified diameter cut at a known angle to the orientation mark, has been developed to allow accurate measurements of planar orientations (Blenkinsop & Doyle 2010).

Discussion

The most common industrial method of collecting structural data from core currently uses α and β angles measured in a core frame of reference. The unified system for collecting structural data suggested here is based on these angles, with the addition in some cases of a length measurement. Therefore it can be taught easily, and readily incorporated into a standard structural measurement routine that enables efficient digital data capture and integration. A photographic method for collecting structural measurements (https://www.groundmodellingtechnologies.com/) utilises an image of core in a core tray: it remains to be seen how this could be utilised for vorticity vectors and fold hinges.

The early adoption of the unified system proposed here, while full core is available before it has been cut for assay, may pay dividends at later stages of a mining project. Otherwise such core may need to be revisited for additional structural measurements, particularly as new structural models are developed. While it is possible to make measurements on half core by the methods in Blenkinsop & Doyle (2010), it is more time consuming, and there is less information available compared to full core. In addition there is the risk of destroying core that contains the orientation mark. The demand for larger sampling volumes in deposits with a high nugget effect (e.g. Dominy *et al.* 2000) or for geometallurgical studies may necessitate complete destruction of core.

In response to the cost of obtaining drill core, new technologies are being developed that may replace some of the functions of core collection, by for example downhole logging and imaging (http://detcrc.com.au/about/goals/). Coiled tubing drilling is also being investigated as an exploration tool in the minerals industry (http://detcrc.com.au/programs/program-1/project-1-1/), entailing no core retrieval. These developments reinforce the importance of utilising what may be very limited core to the fullest extent, and therefore the advantages of the system advocated here.

One potentially serious problem of using a core frame of reference is the possibility that structural measurements are collected but not processed until a later time when the core is no longer accessible. This means that the geologist has no ready appreciation of the geographical orientations of the features being measured while collecting data. Such a divorce between structural data collection and appraisal has several adverse consequences. Hypothesis development and testing is precluded until later. Anomalous observations or variations in orientations are not recognised, and cannot be allowed for in a data collection strategy. Therefore potential errors, including core orientation problems as well as incorrect data measurement, cannot be checked. These problems can be solved by immediate (real time) processing of core angle measurements on site. Ideally, measurements should be entered directly into a logging form or spreadsheet that calculates the true geographic orientations, and preferably plots them on a stereonet as the core is being logged. In addition, the use of a "rocket launcher" is strongly advocated for occasional pieces of core, as a check on the core angle measurements, and to convey a realistic picture to the geologist (Vearncombe & Vearncombe 1998).

This study has been based on core from structurally controlled hydrothermal mineral deposits. However it is clear that petroleum cores also have a variety of interesting structural features (e.g. Hesthammer 1998; Hesthammer & Henden 2000; Porter *et al.* 2000; Hillier & Cosgrove 2002). With the availability of orientated and inclined core (e.g. Follows 1997), the techniques suggested above could also be applicable in the hydrocarbon industry.

Conclusions

A unified system of structural observations in core is proposed, based on angles and lengths measured in a core frame of reference. The system relies on the generalised use of β angles, combined with some linear measurements. It is capable of measuring planes, lines within planes, fold hinges and hinge surfaces, and comprehensive analysis of shear zones and faults. Core is particularly useful for the analysis of shear zones. The vorticity vector can be readily located, more conveniently than in many outcrops, because of the full view of the shear plane afforded in core. All the methods described for full core can be adapted for half core. Widespread use of, and familiarity with, angular measurements on core makes for ready adoption of this unified method with modest training requirements. Structural measurements from core may become even more important in the future as exploration moves under cover, and there is pressure to acquire less core.

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References

BLENKINSOP, T. G., & DOYLE, M. G. 2010. A method for measuring the orientations of planar structures in cut core. *Journal of Structural Geology*, **32**, 741–745.

DAVIS, B., & COWAN, J. 2012. *Oriented Core-What the...In:* Vearncombe, J. (ed) *Structural Geology and Resources*, Australian Institute of Geoscientists, Bulletin **56**, 61-63.

DOMINY, S. C., ANNELS, A. E., JOHANSEN, G. F., CUFFLEY, B. W. 2000. General considerations of sampling and assaying in a coarse gold environment. *Applied Earth Science*, **109**, 145-167.

FOLLOWS, E. 1997. Integration of inclined pilot hole core with horizontal image logs to appraise an aeolian reservoir, Auk Field, Central North Sea. *Petroleum Geoscience*, **3,** 43–55.

HESTHAMMER, J. 1998. Integrated use of well data for structural control of seismic interpretation. *Petroleum Geoscience*, **4**, 97-109.

HESTHAMMER, J., & HENDEN, J. O. 2000. Fault orientation from unoriented cores. *American Association of Petroleum Geologists Bulletin*, **84**, 472-488.

HILLIER, R. D. & COSGROVE, J. W. 2002. Core and seismic observations of overpressure-related deformation within Eocene sediments of the Outer Moray Firth, UKCS. *Petroleum Geoscience*, **8**, 141–149.

HOLCOMBE, R., 2013. Oriented drillcore: measurement, conversion and QA/QC procedures for structural and exploration geologists. http://www.holcombecoughlinoliver.com/.

Jiang, D., Williams, P. F. 1998. High-strain zones: a unified model. *Journal of Structural Geology* **20**, 1105-1120.

Laing, W. B. 1977. Structural interpretation of drill core from folded and cleaved rocks. *Economic Geology*, **72**, 671-685.

Means, W. D., Hobbs, B. E., Lister, G. S. and Williams, P. F. 1980. Vorticity and non-coaxiality in progressive deformation. *Journal of Structural Geology,* **2**, 371-378.

Marjoribanks, R. W. 2009. *Geological methods in mineral exploration and mining*. Berlin; New York: Springer.

Paulsen, T. S., Jarrad, R. D., & Wilson, T. J. 2002. A simple method for orienting drill core by correlating features in whole-core scans and oriented borehole-wall imagery. *Journal of Structural Geology*, **24**, 1233-1238.

Porter, J. R., Knipe, R. J., Fisher, Q. J., Farmer, A. B., Allin, N. S., Jones, L. S., Palfrey, A. J., Garrett, S. W. & Lewis, G. 2000. Deformation processes in the Brittannia Field. UKCS. *Petroleum Geoscience*, **6**, 241-245.

Robin, P. Y. F., Cruden, A. R. 1994. Strain and vorticity patterns in ideally ductile transpression zones. *Journal of Structural Geology* **16**, 447-466.

Scott, R. J., & Berry, R. F. 2004. A new method for obtaining and quantifying the reliability of structural data from axially-oriented drill core using a fabric of known orientation. *Journal of Structural Geology*, **26**, 643-658.

Stanley, C. R., & Hooper, J. J. 2003. POND: an Excel spreadsheet to obtain structural attitudes of planes from oriented drillcore. *Computers and Geosciences*, **29**, 531-537.

Tikoff, B., & Fossen, H. 1993. Simultaneous pure shear and simple shear: The unifying deformation matrix, *Tectonophysics*, **217**, 267–283, doi:10.1016/0040-1951(93)90010-H.

Tikoff, B., & Teyssier, C. 1994. Strain modeling of displacement-field partitioning in transpressional orogens. *Journal of Structural Geology*, **16**, 1575–1588, doi:10.1016/0191-8141(94)90034-5.

VEARNCOMBE, J., & VEARNCOMBE, S. 1998. Structural data from drill core. *In*: Davis, B. and Ho, S.E. (eds) *More meaningful sampling in the Mining Industry*,. Australian Institute of Geoscientists, Bulletin **22**, 67-82.

XYPOLIAS, P. 2010. Vorticity analysis in shear zones: A review of methods and applications. *Journal of Structural Geology* **32**, 2072-2092. doi:10.1016/j.jsg.2010.08.009

Figures

Fig. 1. Some common tools for measuring structures in core.

a) Rocket launcher

b) Template (Scott and Berry 2004 version)

c) Rat-trap

d) Core protractor

Fig. 2. α-β method for measuring the orientation of planes or planar fabrics in orientated drill core. α is the angle between the core axis and the long axis of the ellipse formed by the intersection of a plane with the core. β is the angle measured from the bottom-of-core mark to the ellipse long axis, measured clockwise looking down core. The lower hemisphere, equal area stereoplot shows the construction needed to find the true orientation of the plane using α and β, and the orientation of the core. The plotting procedure is described in detail in Holcombe (2013).

Fig. 3. γ method for measuring the orientation of a line within a plane. γ is the angle from the ellipse long axis to the lineation. Stereoplot shows γ measurement.

Fig. 4. βL method for measuring the orientation of a lineation in a plane. βL is the angle from the bottom of core mark to the lineation within the plane, which can be measured readily with a core protractor. Stereoplot shows angular relationships and how to find the true orientation of the lineation from the βL measurement and the orientation of the plane and core axis.

Fig. 5. Appearance of folds in core. a) Multiple folds in gneiss, expressed as figure of eight and ellipses on the core surface. Folded surfaces marked in red dashed lines; fold hinge surfaces in yellow. b) Fold hinges (yellow dots) and hinges surfaces (red lines) on adjacent folded surfaces.

Both cores from Tropicana gold deposit, courtesy of Anglogold Ashanti Australia Ltd.

Fig. 6. Measurements needed to find fold hinge orientations from the intersections of a fold hinge on core. U, D are the up- and down-hole intersections of the hinge with the core. They are characterised by angles βU and βD measured from the bottom of core mark (BOC). UD is the distance from U to D parallel to the core axis, measured positive downhole.

Fig. 7. Appearance of two types of shear zone in core, with varying relationships between lineation and vorticity vector. The shape and orientation of the porphyroclasts are shown to be approximately representative of the shape of the finite strain ellipsoid. a) Simple shear dominant (*sensu* Tikoff and Fossen 1993). Lineation (yellow lines) is parallel to the shear direction. b) Pure shear dominant. Lineaton is parallel to the vorticity vector and perpendicular to the shear direction.

Fig. 8. Shear zones and shear sense indicators in core. a) Shear plane (yellow line on core) can be measured by the α-β method. The vorticity vector (purple line) and shear sense (yellow half-arrows) are identified within the shear plane by the σ clast. The vorticity vector can be located by the angle βV from the Bottom of Core mark (BOC). b) S-C fabrics and vorticity vector in core.

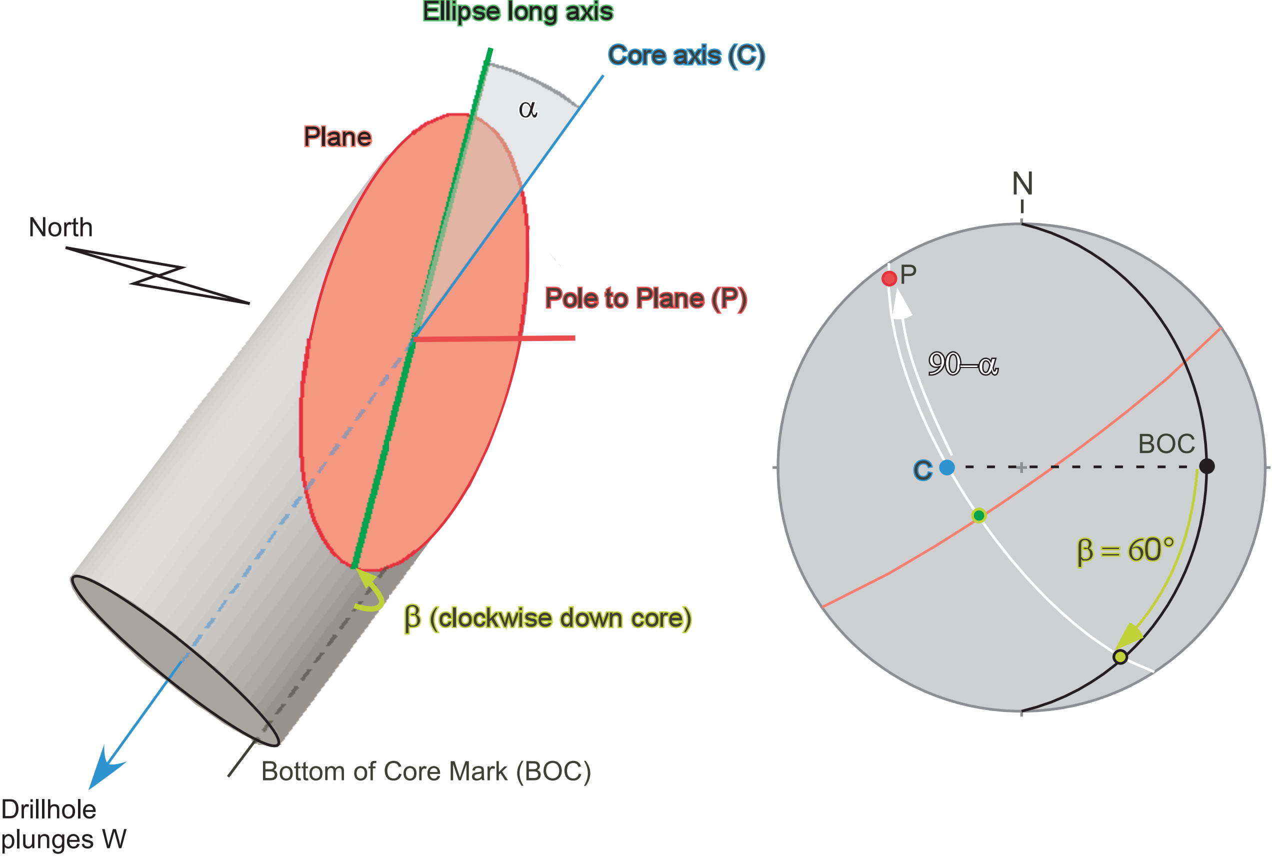
Fig. 9. Measurement of the vorticity vector in core. The vorticity vector is located by the βV measurement from the Bottom of Core (BOC) measured clockwise looking down hole. The shear direction (SD) is perpendicular to the vorticity vector. Stereoplot shows angular relationships and construction necessary to locate the vorticity vector from the βV measurement, and the shear direction 90° from the vorticity vector in the shear plane. The vorticity is anticlockwise (looking down plunge), which implies a reverse sinistral sense of shear.

Fig. 10. Appearance of S-C structures in core, and their use to find the vorticity vector, shear

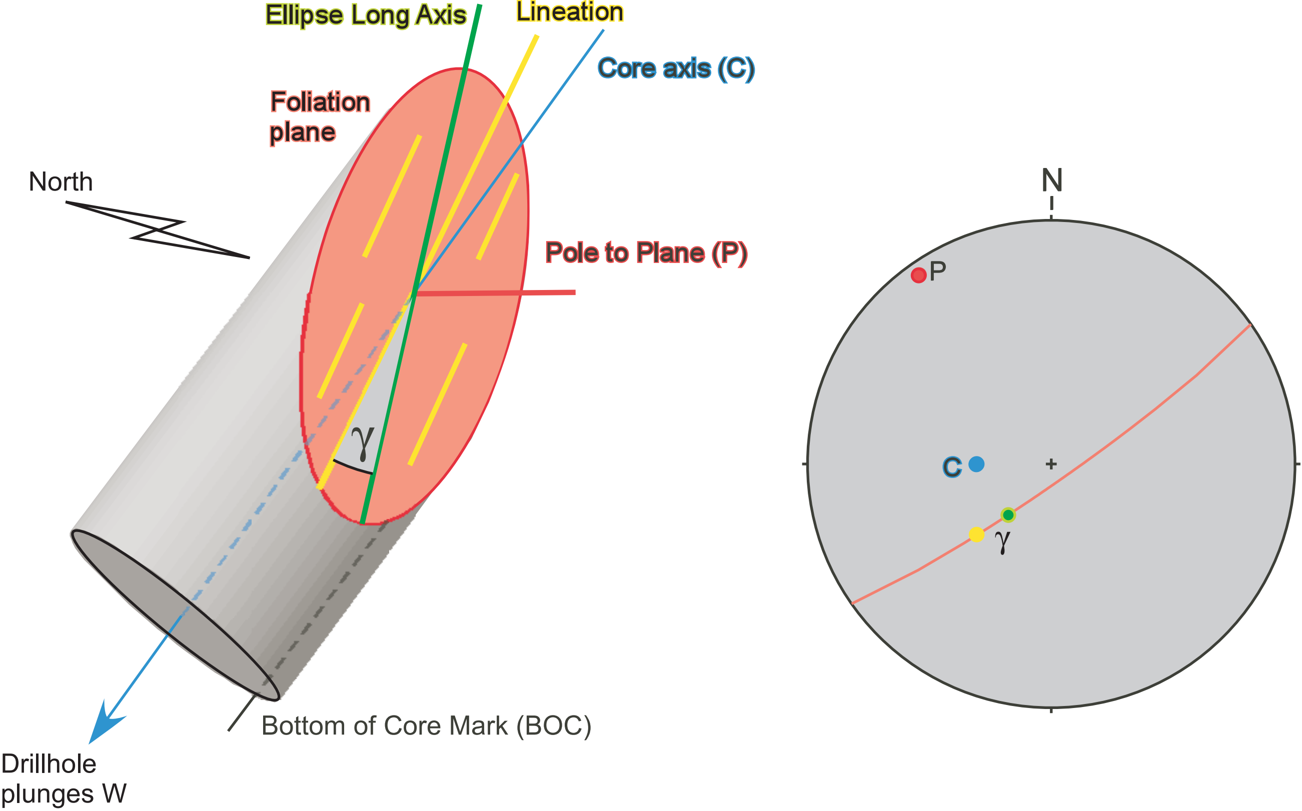
direction (SD) and sense of shear. The S and C planes can be measured by the α-β method. The S-C intersection is parallel to the vorticity vector, and perpendicular to the shear direction. The sense of shear is given by the sense of rotation from the S fabric to the C fabric. Similar relationships exist for S and C' planes.

Fig. 11. Two situations in which kinematics are difficult or ambiguous to specify using typical kinematic terms. a) It is difficult to specify the hangingwall of a near vertical shear plane. The uphole side is unambiguous. b) It is difficult to know the exact dip direction of a near horizontal surface, and therefore to evaluate whether it is dextral or sinistral. Again, the uphole side of the shear is unambiguous.

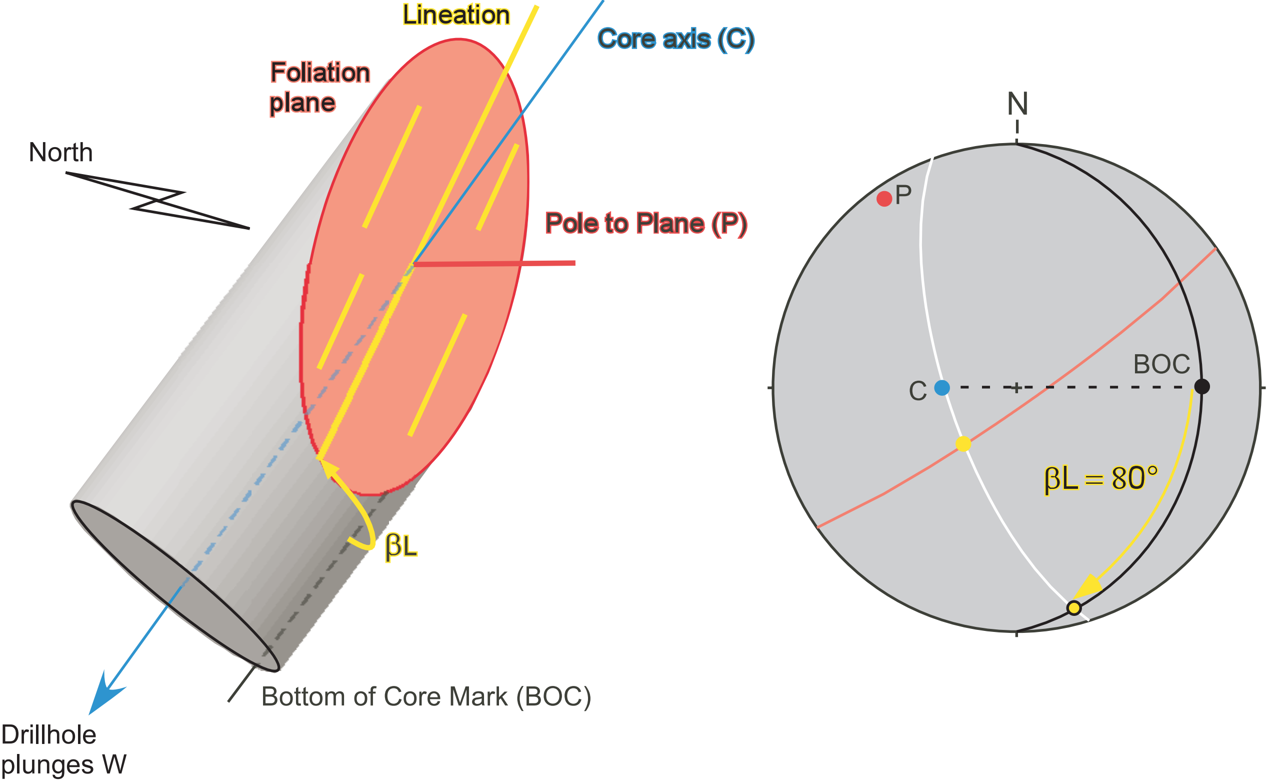

a)
b)
40 50 60 70 80 90
90 – 270
70 – 290
50 – 310
30 – 330
10 – 350
c)
d)
TPD253
SOH 210.9–218.5

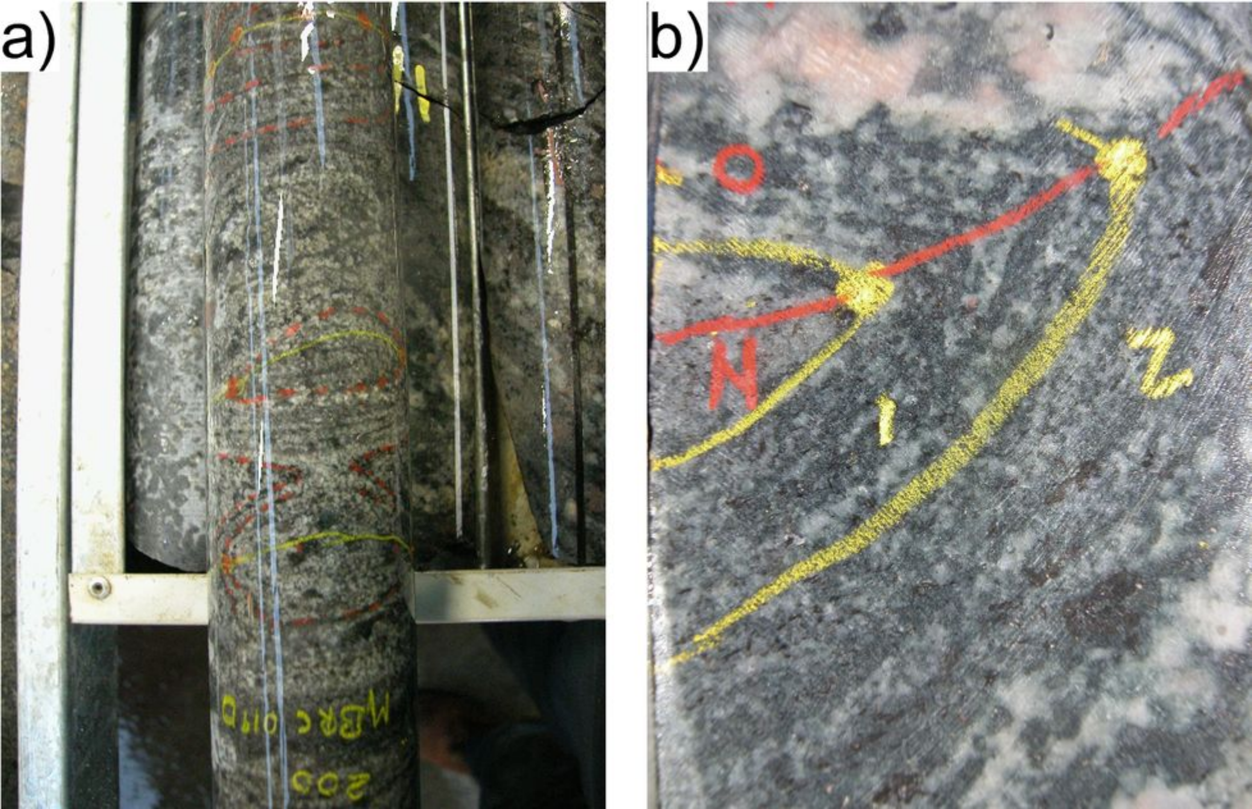


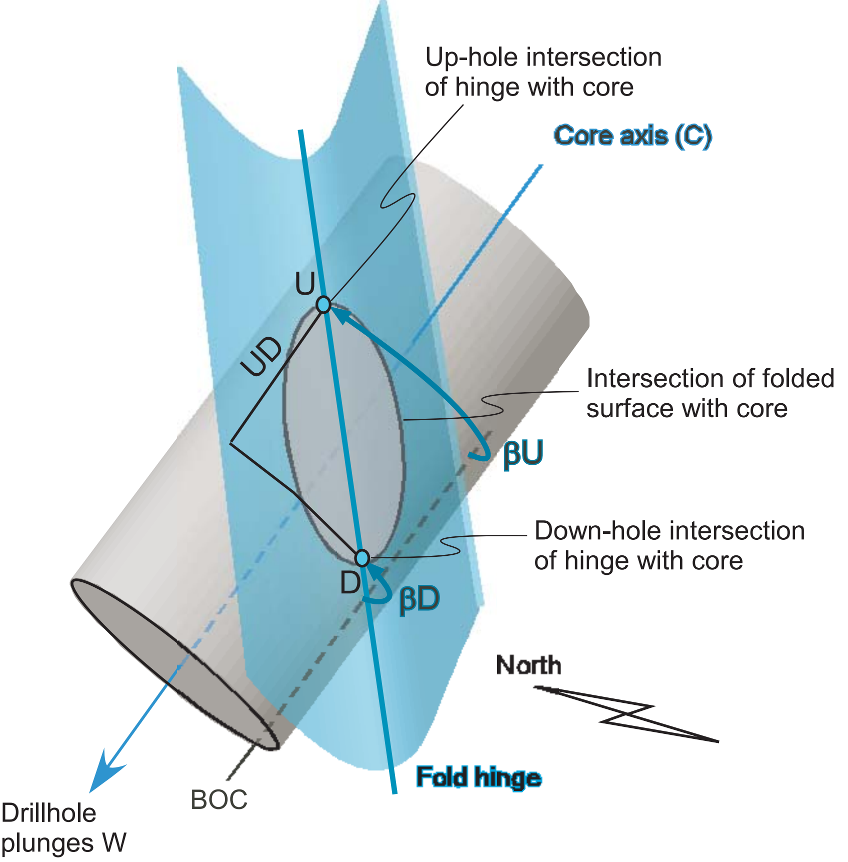
Ellipse long axis
Core axis (C)
α
Plane
North
Pole to Plane (P)
β (clockwise down core)
Bottom of Core Mark (BOC)
Drillhole
plunges W
N
P
90−α
BOC
C
β = 60°

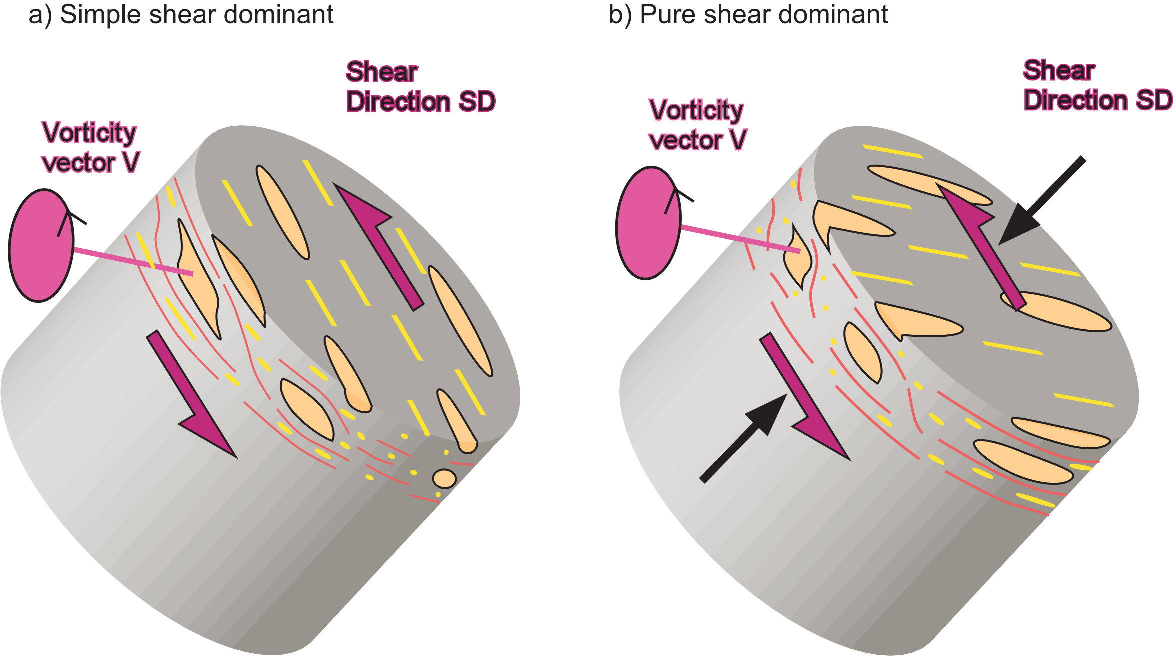


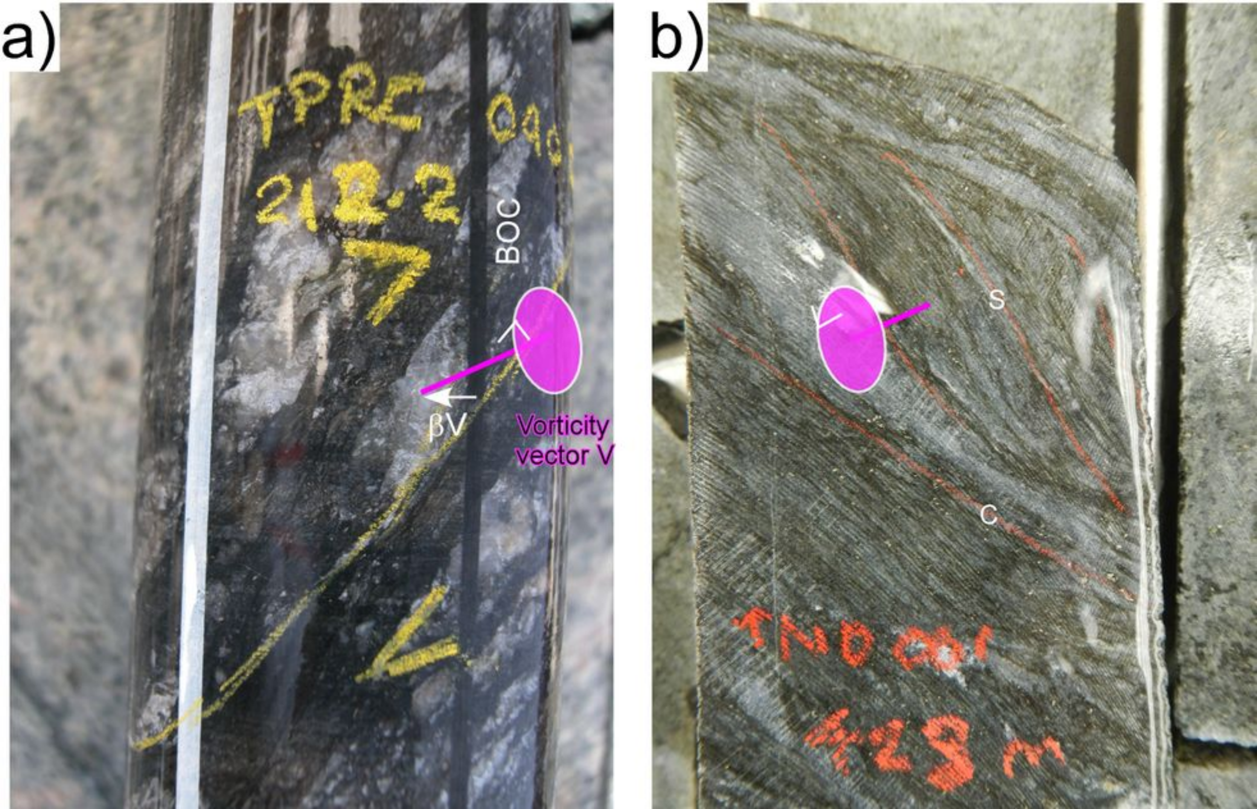
Ellipse Long Axis
Lineation
Core axis (C)
Foliation plane
North
Pole to Plane (P)
γ
Bottom of Core Mark (BOC)
Drillhole plunges W
N
P
C
γ

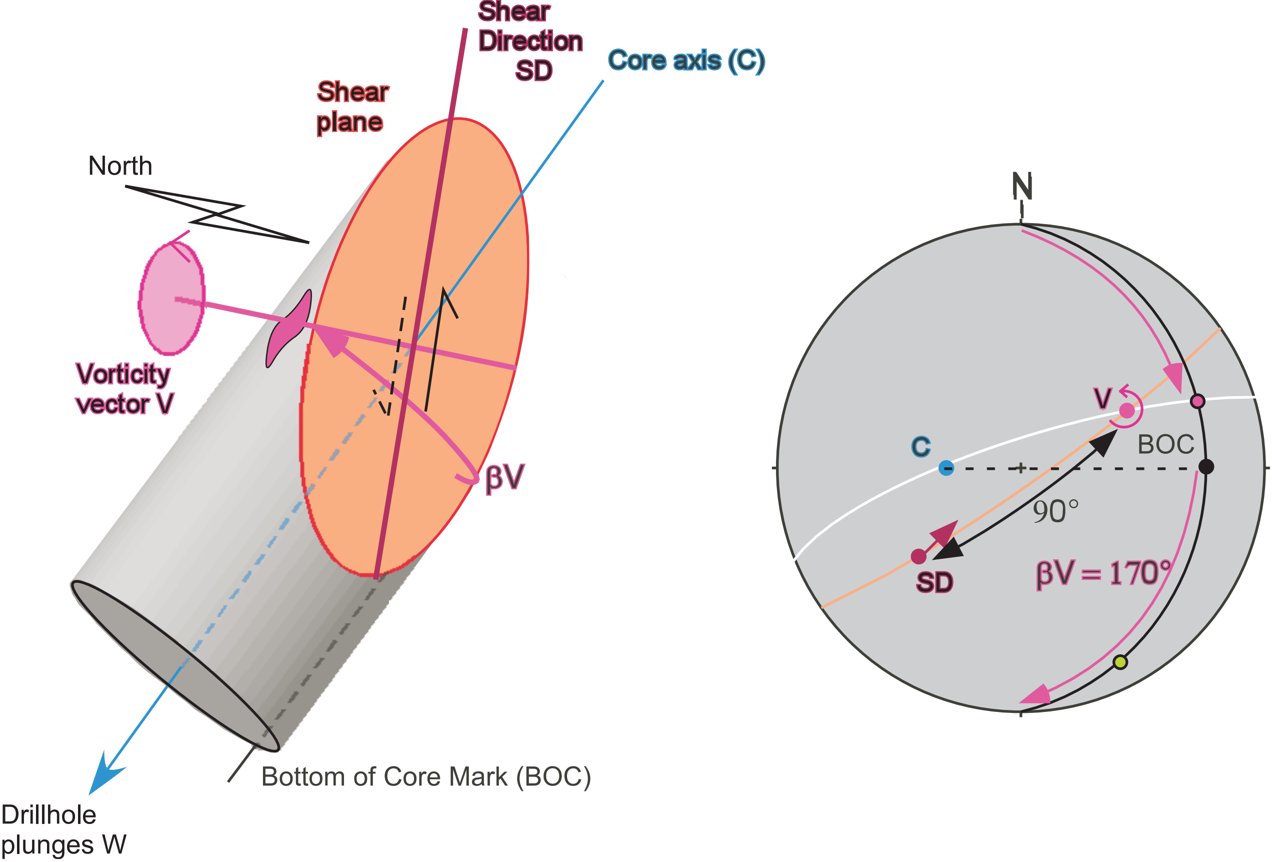

Lineation
Core axis (C)
Foliation plane
North
Pole to Plane (P)
βL
Drillhole plunges W
Bottom of Core Mark (BOC)
N
P
BOC
C
βL = 80°

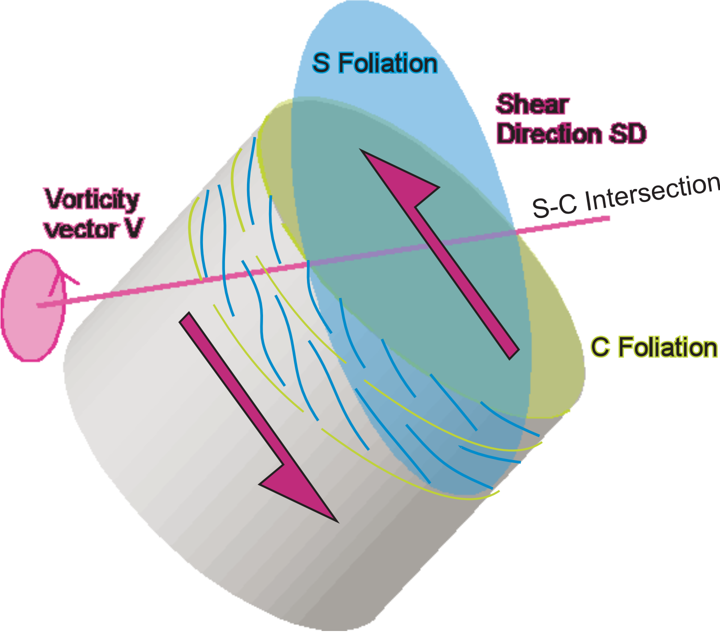

a)
b)

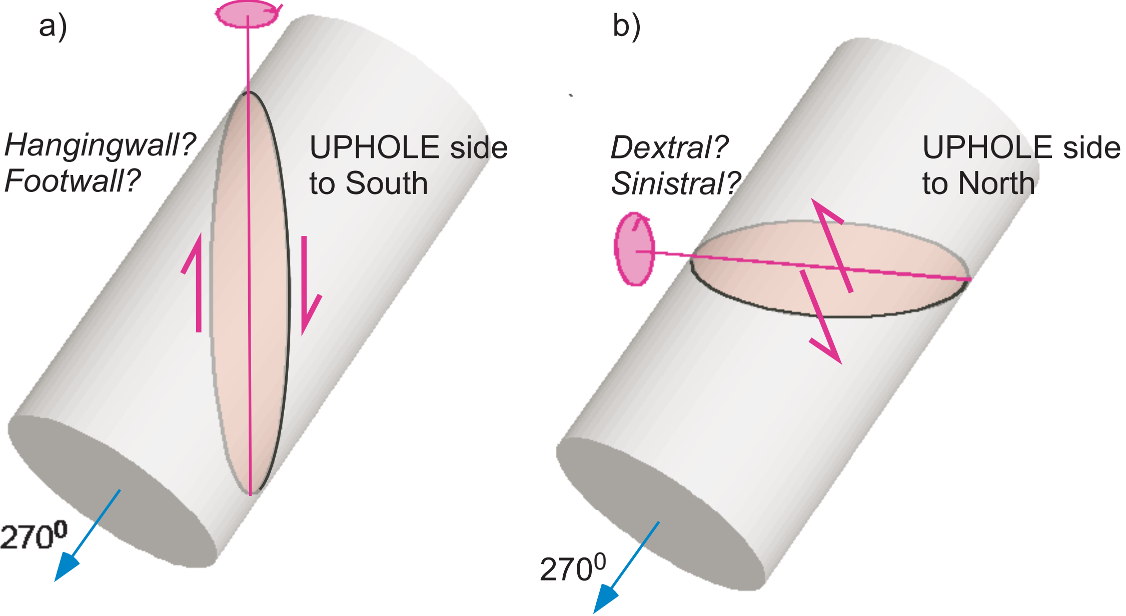

Up-hole intersection
of hinge with core
Core axis (C)
U
UD
Intersection of folded
surface with core
βU
Down-hole intersection
of hinge with core
D
βD
North
Fold hinge
BOC
Drillhole
plunges W


a) Simple shear dominant
Shear
Direction SD
Vorticity
vector V
b) Pure shear dominant
Vorticity
vector V
Shear
Direction SD


a)
BOC
βV
Vorticity vector V
b)
S
C


Shear
Direction
SD
Core axis (C)
Shear
plane
North
Vorticity
vector V
βV
Bottom of Core Mark (BOC)
Drillhole
plunges W
N
V
C
BOC
90°
SD
βV = 170°


S Foliation
Shear
Direction SD
S-C Intersection
Vorticity
vector V
C Foliation


a)
Hangingwall?
Footwall?
UPHOLE side
to South
270⁰
b)
Dextral?
Sinistral?
UPHOLE side
to North
270⁰