2024

SOME MUSINGS ON DRILL CORE ORIENTATION AND DIRECT MEASUREMENT OF STRUCTURAL DATA

BRETT DAVIS – OLINDA GOLD PTY LTD

Contents

Introduction

This contribution has been sponsored by a long career of dealing with oriented diamond drill core, which has generated lots of discussions, including some protracted ones on LinkedIn. Over the years I have looked at uncountable metres of core, the majority of it oriented. Given my grey hair, this means that I started back in the good ol' days when methods such as the spear and mechanical methods like Ballmark and Ezy-Mark were the common orientation tools. Since then, electronic core orientation has taken precedent and is the norm, regardless of the device used. Now, I've had numerous rants on the foibles of getting core with good quality, high confidence marks and even written a few articles (references toward the end). As such, I'm not going to go down that rabbit-hole here. Rather, I want to make a few comments about the extraction of data from the core.

Seriously, I really put this post together as a light-hearted discussion of core orienting frames because I had been collecting photos of the various species I had encountered. From there, the document grew as I added stuff. There is discussion of alpha-beta devices, but it is not exhaustive. There are also some serious comments, but nothing to get bitter and twisted about. Enjoy the commentary and, if you don't like my prose, marvel at the ingenuity (and common lack of) that has spawned some of these devices. Or simply ignore the post and jog on – I actually don't care if that's your choice!

My methodology for data collection

Firstly, in the following discourse I am going to assume that the core has a high-quality, high-confidence orientation line that will be the reference for compiling a database of structural measurements. In reality, this assumption is dangerous and needs to be fact-checked.

My method for interrogating core is to document every structure from which an orientation measurement can be taken. I then compile the structures on a timeline, so that I know the relative ages/overprinting. From here I collect orientation data for each population of structures. This allows me to compare each population of structures with any of the others. Importantly, this also allows me to compare their locations and orientations in space with the assay data, thereby providing information on grade trends and which structures are responsible for influencing/controlling grade.

If more than one set of structures belongs to the same population, it is easy to combine them. However, if the individual populations are not defined at the start, and are lumped, then it is typically impossible to separate them later. I shouldn't have to state this, but I have had the misfortune of dealing with people who simply don't get it. In one case, the same person made a comment that bewilders me to this day, saying the following about a poly-deformed bunch of rocks with strong structural controls to mineralisation – 'I don't want to see structure complicate the deposit'. But I digress.

Methods of structure measurement and orientation line-types

There are three principal ways to collect orientation data from oriented core:

- The most common way is to measure structures indirectly using a device that lets you record alpha (apparent dip) and beta (apparent dip-direction) for planar structures. Lineations can also be measured on an exposed plane as a gamma value. After that, we defer to software to do the calculations to give us the true dip and dip-direction for planes and true plunge and plunge-direction for lineations. Note that we need the alpha and beta values for the plane containing the lineation, because the gamma value in isolation is not enough to give plunge and plunge direction. Various authors have provided guides on how to do this and one of the good ones I will reference is that of Rod Holcombe (2017). Alpha-beta devices come in many forms, from wrap-around strips to solid devices that hold the core (e.g. Kenometers) to electronic gizmos like the iQ-Logger.
- The second method, which is effectively the virtual equivalent of using an alpha-beta device, is to take measurements from photographs of oriented core where the orientation line and depth marks are visible. Planar structures are digitized and software does the rest. Note that this is only good for planar data. Colleagues who have advanced this method include John Wilson and Grant Wilson from UCP Africa. This has been refined to the point where representative results have been achieved from half-core, utilizing templates in one form or another to continuously check the accuracy and precision of instruments. The method of virtual measurement is a particularly important one, especially if access to site is impossible, or legacy core has been lost/destroyed.
- The other way to measure structures is to do it directly, using a compass and a core orientation frame (sometimes called a rocket launcher).

A fourth, virtually un-used (at least to my knowledge) method is to x-ray the core, register the core orientation, and take the structural trend in 3D. This is time consuming and limited in the amount of core that can be processed, so I won't discuss this further. With respect to the bullet points above, I use both the direct measurement (rocket launcher) and alpha-beta methods.

At the end of the day, I am trying to collect high quality datasets, with the thesis being that it is better to get a small population of good measurements than a large population of rubbish ones. In this respect, I think it is crazy to have more than two types of orientation lines on the core. Line types should be restricted to a high-confidence line or a line that indicates no confidence. I see no logic in trying to incorporate measurements from lines that might or might not be correct and have been deemed 'low confidence'. You are only going to pollute your database of good measurements with those that are crap. Would you incorporate gold assay values that might or might not be okay into your resource calculations? If not, why do this for structural data that is helping to define the geometry of your resource?

Direct measurement of structures

Most of this portion of my discourse is a documentation of types of core orienting devices I have encountered. So, it's a bit of a photo catalogue of the good, the bad, and the ugly, along with my comments on their reliability and whether I think they are good or bad in general. I'm not going to go into the use of a compass to measure a structure. I could say that you really need to go and do a refresher if you can't measure a dip and dip-direction. That said, I can't really make the same comment about measuring lineations because I would generously say that only about 10% (probably less) of geologists know how to do this. Sad but true.

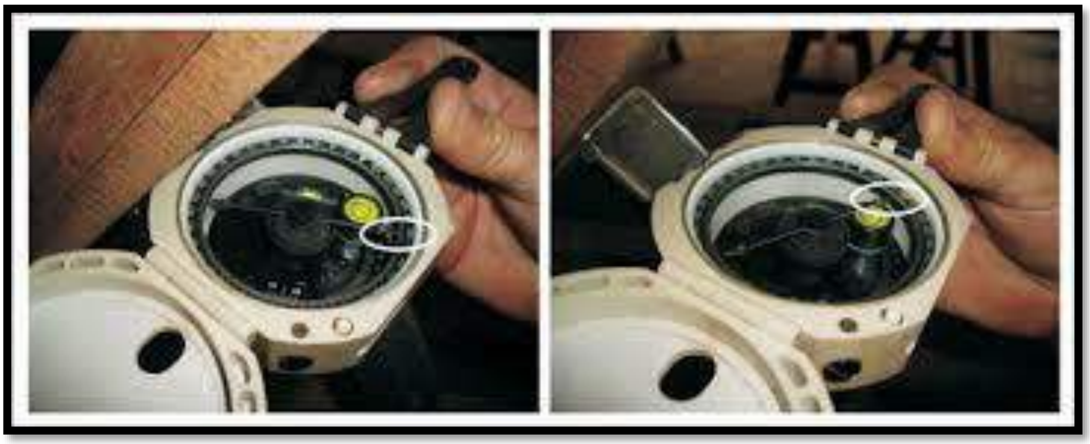
A core orientation device should be able to position and hold your drill core in an orientation that is the same as it was prior to drill sampling. So, it has to duplicate the azimuth and plunge of the drill hole at the position from which the core was collected. We all know that the longer a hole is, the more it tends to deviate in orientation. So, the ability to adjust the azimuth and plunge of your core sample in your orientation device to mimic this, according to the hole survey, is necessary.

Types of drill core orientation devices I've seen – good, bad, and perplexing

In this section I have illustrated a number of variations on the theme, and these are shown in no particular order of importance/elegance. They are simply ones that I thought needed documenting for the sake of education and humour. Many are elegant in design but fall over in terms of technical details.

The first device is one I encountered at Golden Star's Bogoso core shed many years ago. It has an okay design, but there are several issues:

- The plunge of the hole is duplicated by lifting the wooden cradle and putting a pin in the hole of the metal arm underneath it. Unfortunately, this restricts adjustments to increments of a few degrees. This can result in 'starfish' patterns on stereo plots.
- The device is part of a larger table necessary to house the metal arm under the cradle. So, it is not as easily moveable as it could be, something that is necessary for reorienting core to accommodate changes in hole azimuth.
- The most troublesome thing with this device is illustrated by the pen magnet hanging underneath it. The device has been constructed with steel that affects the needle of the compass. A test of this showed deflections in the needle by up to 30 degrees, as shown in the photos below the device.



Core orientation device – Golden Star, Bogoso

The next device is one that was constructed to review core orientation at Newmont's Ahafo deposit. Once again, this was a couple of decades ago and the senior geo I dealt with has left. This was a blessing for core orientation procedures because he was completely useless and had a 'I don't care – I'm too important and don't want to leave the air conditioning' attitude. To give you an idea, he wasn't checking the orientation procedure, which allowed the drillers to get away with only orienting core every 60m or so. When my colleague and I secured 20m of angle iron and laid out a similar length of intact core, we found the 'orientation' line spiralled around the core in some cases.

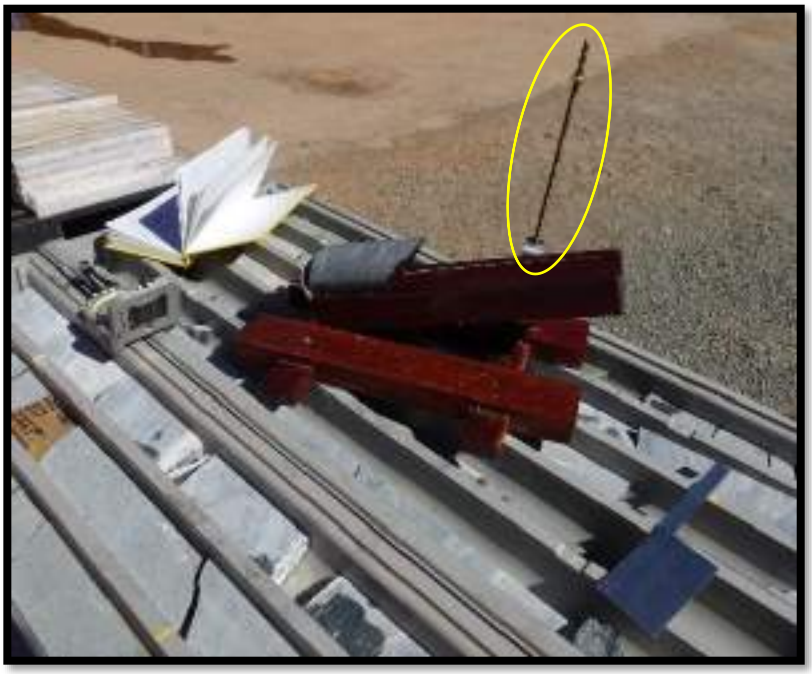
As can be seen on the annotated wooden stops, the device can be adjusted by five-degree increments. Once again, this causes artificial data spacing. Also, this device had incorporated steel nails into the design. So, an elegant device, but again with limitations.

Core orientation device – Ahafo, Ghana.

Staying on the theme of magnetic material, the next example has a mountain of it. If we ignore the fact that half of the device is magnetic, we can see that the general idea is okay. However, it contains one of my pet hates with these devices, namely the necessity to spend ages moving a nut up and down a threaded rod to change the hole plunge. When dealing with different holes that have different plunges, it becomes really tedious to adjust. I have no idea why some manufacturers still persist with this style of adjustment, because it greatly impedes productivity and acts as a deterrent to geologists using a core orienting frame.

The most annoying angle adjustment mechanism around – the threaded rod with a nut that has to be tediously screwed up and down.

In similar fashion, the photos on the next page show another example of the tedious nut-twiddling adjustment mechanism on a core orienting frame I used on a job in Australia. I had to review a lot of drill holes with different plunge values and an inordinate amount of time was required to adjust the device. In the end, it was more practical to put the device in a cupboard (I couldn't convince the client to simply throw it away and get a better device) and use a bucket of non-magnetic sand to place the core in.



Example of a core orienting frame with the horrible threaded rod adjustment design

The next example is an attempt to get away from having magnetic material (if you ignore the couple of nails at the end near the bottle). There are a few design flaws, but it is a good attempt. The plywood holding the brown poles that cradle the core gets in the way of the core. Also, there is no effective way to stop the piece of plywood from sliding if a heavy piece of core is placed in the cradle. Overall, though, this is a good attempt and easy to move around.

An interesting and generally workable core orienting frame. A couple of steel nails in the base. One of the main impediments, though, is that the board for adjusting the angle impinges on the area for cradling the core between the two brown sticks. An interesting design though.

Believe it or not, the next device is quite good. As noted on the frame, it is a first attempt. It is all wood with no metal parts and can hold an appreciable stick of core. And, yes, the plastic adjusting nut is the same one that attaches toilet seats to their thrones.

The Julie MK1 core orientation frame. All timber and a very useful prototype built by one of the geologists working on the project. Hard to see the orientation line though, due to the cradle being solid and having the wooden support for adjusting the angle behind it.

The core orienting frame in the next image worked a real treat. It was used by the guys in the core-yard at Aykem, Ghana, and is another example of a novel design. The wooden wedge was slid along under the triangular frame to change the hole plunge. The device could hold a sizeable interval of core and it could be easily rotated on the table to the appropriate azimuth.

For the record, the data collected by the three local geologists I worked with, using core that had been oriented with a spear, was some of the best I have ever seen. It just goes to show that a little care and attention from the drill rig through to the core-yard can go a long way toward compiling a quality dataset.

Core frame with angle adjustment via movement of a wooden wedge.

The next device is clunky, but good. It is sturdy and can hold a reasonable length of drill core. The frame is constructed from aluminium, so it is non-magnetic. Importantly, it is easy to quickly adjust the hole plunge by loosening and tightening the brown screws on the side. Despite the core orienting frame being okay, this project contained some of the worst examples of core orientation mismanagement I have seen. The program had obviously not been monitored because every hole except one was a litany of rotated core that had wrongly been marked up as containing high confidence orientation lines. This device was at Crocodile Gold's Cosmo deposit in the Northern Territory. No-one seemed to know the origin of the device, but it looks uncannily like the one manufactured by Paul Givney, which has been around for decades and is shown in the succeeding photos.

A chunky but workable frame located on plastic crate and plastic pallets in the car park of the project.

The next device is manufactured by Paul Givney and was designed by Bill Laing and Ken Lawrie when they were at James Cook University in the 1980s (yes, way back then, when there was no such thing as a laptop, drone, or OH&S constraints!). Paul was a technician in the Geology Department at the time. He has since left but still produces these on demand. They now come in a sturdy plastic case.

This device is my orientation frame of choice for several reasons:

- It is easily transportable, being of manageable size and weight.
- It is remarkably sturdy and can take very large pieces of core.
- It is very easy to quickly adjust the device to account for changes in drill hole orientation.

The disadvantage is that they are like any of the other commercially available core orientation devices, being very expensive.

The ex-JCU core orienting frame – my personal favourite.

And now to what is probably the most complex core orienting device on the market and, from what clients have told me, the most expensive. This device has more pulleys and dials and wigwams for a goose's bridle than Peter Criss' drum kit (Peter Criss was the drummer for KISS, one of the most successful rock groups of my youth). There are a number of problems and limitations with this device:

- It is really heavy, taking two people to safely move it around.
- It is really big, so it is not easily transportable and certainly not something you can take on a plane to a job in another state/country.
- If the rubber band/belt breaks, then you can't easily fix it on the spot.
- You can't measure lineations with it.
- I'm not sure if this is the case with all of these starships, but the one in the photo had steel screws holding it together. So, it was not possible to measure structures, such as lineations, with a compass while the core was in the device.

In summary, not my favourite device and one I substituted a bucket of sand for.

A complex, expensive, hard-to-transport device – not one of my favourites.

Alternatives for when you don’t have a core orienting frame

There really aren’t many alternatives to a decent core orienting frame, and there are no alpha-beta devices available. The main alternative is very cheap and easy to construct, being nothing more than a container of non-magnetic sand.

A bucket of non-magnetic sand is no different to a core orienting frame and can hold very large pieces of core if the bucket is large enough. The best buckets are the square ones, because these will allow you to rest the core in one of the corners, which will prevent movement. It is also very easy to quickly adjust the core in the sand to account for changes in drill hole dip and to spin the bucket around for changes in hole azimuth.

Simple but reliable! The good ol’ bucket of non-magnetic sand.

The bad, ugly, and humorous

Human ingenuity can be remarkable. It can also be less than remarkable. Not only that, but there has also been a lot of effort gone into the 'devices' in the next couple of photos. In fact, even more effort than it would take to source a much more useful bucket of sand.

Human inventiveness at it's best.

I'm not really sure what to say with the next 'device'. Is it good? No. Is it bad? Yes, very! Is it ugly? Yes, very very! It's hard to see but a compass rose has been carefully drawn on the concrete floor of the core shed. Why not just get a bucket of sand?

Cardboard tube? Check. Poor design? Check? Useful – leave unchecked!

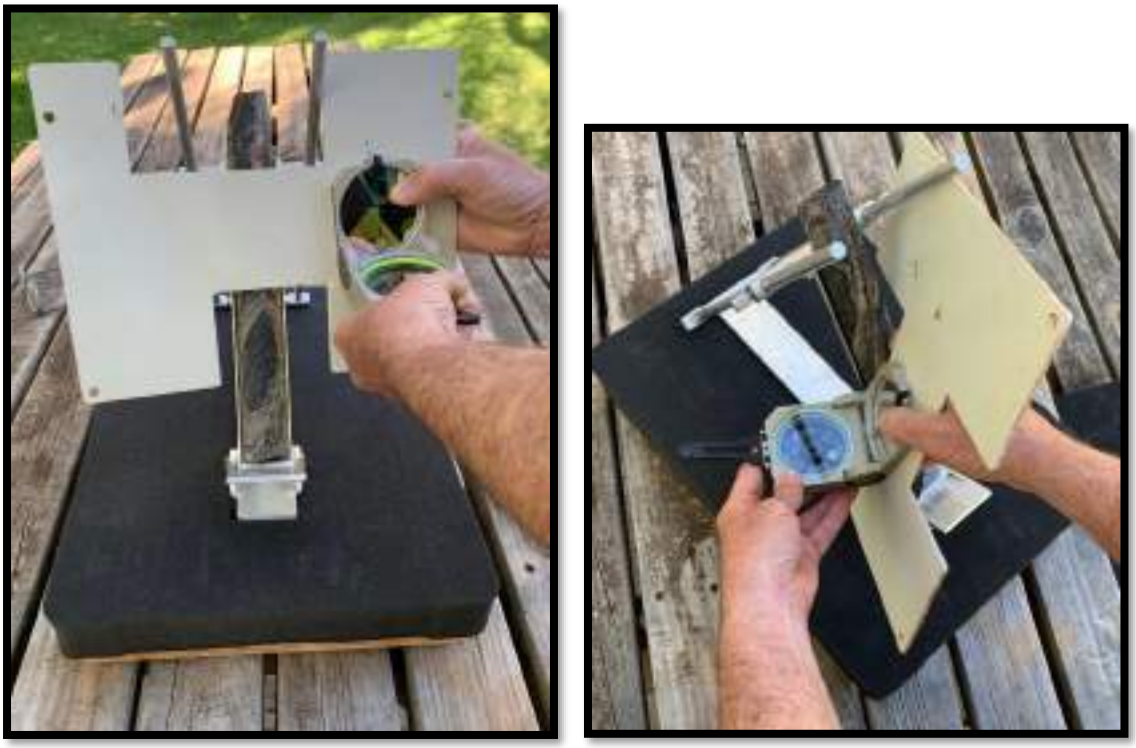
The device below has all the right ideas but has been made with all the bad materials. Once again, the pen magnet is there for reference. In one sense, you have to applaud the guys for making a frame. On the other hand, why do it so badly by using so much magnetic metal.

Magnetic imitation of an otherwise good core orienting frame. Note the red pen magnet.

Advantages and disadvantages

Measurements of planes

Both the alpha-beta and core orienting devices allow for effective measurement of planes. The core orienting frame commonly necessitates the use of a planar piece of material that can be lined up with the ellipse in the core in order to accurately define the structure. This material can be plastic, plywood, your notebook, stiff cardboard etc. Alpha-beta devices do not need this extra piece of equipment. I use a piece of stiff plastic with portions cut out (figure below) to fit around the core and frame, and that allow them to be held easily with the compass.

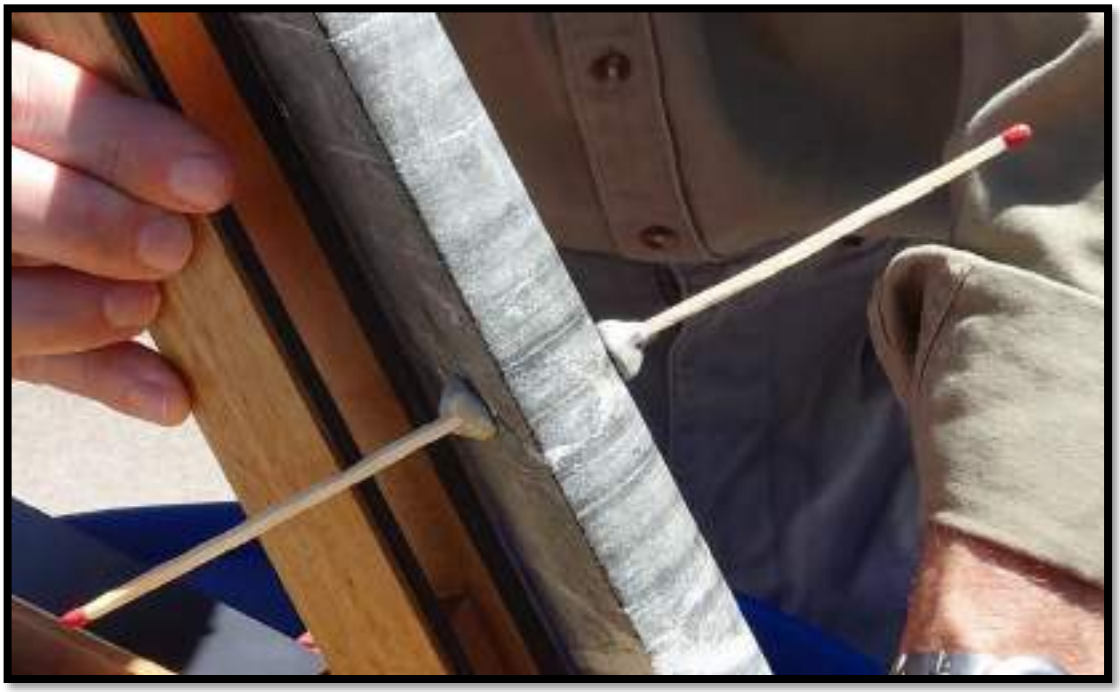


Plane measurement using a proxy.

Measurement of lineations

Lineations are easily measured on exposed planes with a compass. If the lineations are internal to the core interval, e.g. a fold axis, boudin neck etc, non-magnetic proxies for the lineation can be attached to the core and measured. The JCU core orientation kit comes with non-magnetic planes and extenders that can be attached to the core with plasticine that is also included.

Lineations can be measured as a gamma angle on the plane for which alpha and beta are known. Alternatively, they can be treated as a plane by subtending the lineations to the edge of the core and measuring their apparent plunge and apparent plunge direction as alpha and beta for a plane. Rod Holcombe described the procedure in his very good treatment of oriented core in his recently published textbook (Holcombe, 2016).

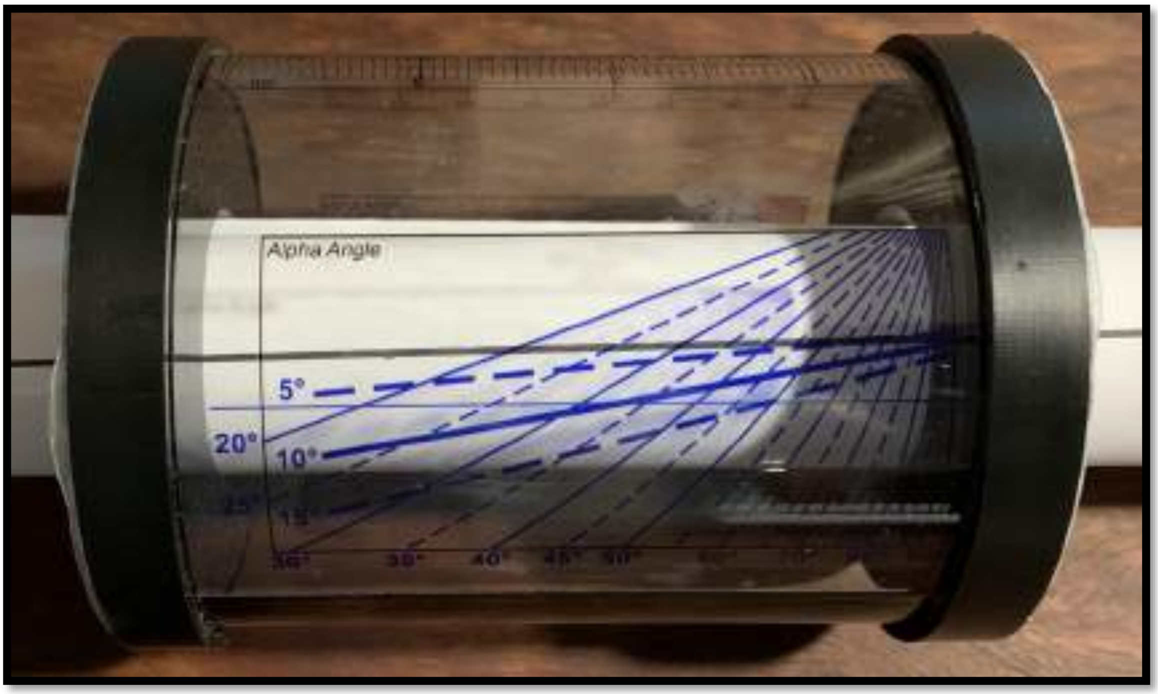


Extenders used as proxies for internal lineations. Big barbeque matches in the top figure are attached to the core with Blu-Tack. The brass ones in the packet in the bottom photo are included with the JCU rocket launcher.

Structures with low alpha angles

Invariably, we will encounter structures at a low angle to the drill core axis. These structures will produce low alpha angles, something that non-electronic alpha-beta devices can't really deal with. The exceptions are solid devices that encircle the core, not the wrap-around strips. Although electronic devices can do this, it is not common to see people taking low alpha angle measurements. Rather, these structures are simply noted as 'parallel to core' when they commonly aren't, or they aren't measured at all. However, such structures are simple to measure in a core orienting frame.

There are implications to structures with low alpha angles and not measuring them. Low alpha angles mean structures are at a low angle to the core axis – if steeply dipping, they will strike at a low angle to drill sections and won't commonly be intersected. So, this leads to two levels of data omission due to uncommon intersection and uncommon measurement.



Alpha-beta devices showing the issues with the measurements of low alpha angles. The lower device can deal with this, but both devices are graduated in 5-degree increments, which is not ideal.

Extracting data from half-core

Just about every geologist who has spent a few years in the industry dealing with diamond drill core will have been involved in a re-log. Invariably, this will mean laying out boxes of core that has already been sampled. If lucky, we will have half-core. If unlucky, the orientation line will have been sampled, or the core will have been quartered. Quarter-core is possible to work with, but it is not ideal, and I avoid it if I can.

Despite the protestations of people who don't want to use a core frame, getting accurate alpha-beta data from half-core is hard. In a core frame it is easy, made more so by the straight intersection lines that the planes make on the cut surface.

Note that some companies have managed to make in-roads into the virtual measurement of alpha-beta from half-core in photos. However, the photography of half-core is rare, and would typically need to be done specifically for the assignment. If this is the case, it would be just as easy to measure it directly. That said, at least the photos remain as a record and can be revisited easily.

Oriented sample mark-up

There will be occasions when an oriented thin section is required. For example, the structural age of mineralisation will need to be established relative to one or more fabrics. I have written a freely downloadable document that details how to do this from oriented core. This is a very simple process with core in a rocket launcher, but next to impossible using alpha-beta devices.

Lack of mandatory equipment

If there is no core orienting frame on site, we can quickly and easily build a proxy, such as a bucket of non-magnetic sand. However, it is pretty much impossible to mitigate against an exploration or mining site that has no compass.

A colleague and I did a one-day consultancy job on site at a nickel mine in Western Australia. We were told that it would be a discussion session, that there would be no field equipment, and that we did not need to bring any equipment other than the obligatory PPE. The core we were shown in the core-yard, after a half-hour deliberation on whether an open core yard in northern Western Australia necessitated the wearing of safety helmets, was incredibly deformed. In fact, it had some of the most pronounced extension lineations I have seen. The core was also oriented. The lineations could not be measured with an alpha-beta device so we asked to use one of the exploration department's compasses. Incredibly, none of the staff had a compass and there was no communal one. In the end, an overseas student managed to find the one he had used at university.

Sometimes, you simply can't win. But the site was incredibly safe!

Location of core frames – the effects of core racking, steel infrastructure etc

A common decry from the alpha-beta advocates (or should I say the core frame haters), is that the core orienting frames necessitate the use of a compass, which can be affected by the local environment e.g. steel infrastructure that is nearby, a pen magnet that you forgot you had in your pocket etc. So, they argue, alpha-beta must be better.

My comment is that you need to assess the effects the local environment might impose on your equipment and mitigate against it. I have seen comments on LinkedIn, in response to my posts, that I agree partly with, but that then migrate to unsubstantiated claims. For example, one colleague stated:

> '*Steel screws are a bit academic if the rocket launcher is going to be used in a steel framed coreshed. What is the rocket launcher being placed on etc etc.*'

I agree with this. However, the follow-on comment by another colleague became more contentious, stating:

> '*I was going to reply to the same effect. The amount of steel and reinforcing in metal core racks, roller racks, concrete floors, sea containers etc all have a huge effect. the same if not more than the screws but harder to quantify. Also, on drill rigs, the amount of steel (and actually trying to sight in rigs), shows that with a sensitive compass, you might have to go 40m away! Set up the rocket launcher on a 44-gallon drum out in a duch camp!*'.

So, some of this I agree with, but 40m, in my opinion, is extreme and unwarranted. Clearly, common sense should prevail if there is that much magnetic interference, and this is a case where alpha-beta is preferred. No problem. My reply to the above comments was to describe my own tests into the effects of steel infrastructure as follows:

> *I've actually done the assessments before by taking a string line from out in the carpark and into the core shed on a few occasions. This is so that I have a uniform orientation reference point for the compass. In most cases I have seen negligible deviations until really close, at least for the case of standard outdoor coreyards with steel racking, until 8-10m away. This has then been compared with alpha-beta to check variability. Within practicality of experience, I set up on non-magnetic tables (eg plastic pallets or drums) at about 10m from racking. In cases where we have an abundance of sea containers and steel sheds, other systems need to be devised e.g. I set a table up in an open area in 44 degree heat at Havieron well away from infrastructure. It was brutal in terms of temperature but had to be done. So, I take your points, but as with use of a rocket launcher, the distance from infrastructure needs to be assessed. If overly magnetic, use alpha-beta (I never once advocated against this and I use it) or reassess your procedure. There are other things too - how magnetic is the equipment you are wearing- hand lens, pen magnetic, tough book, personality?*

Don't get me wrong – I appreciate the feedback that the people above gave. It enhanced the discussion, and I don't criticize their views, even if I do not agree entirely with them.

So, let's discuss how to mitigate the effects of the local environment and your equipment. I suggest the following, which is likely not an exhaustive list, but is hopefully a decent start.

- Make sure the core frame is located on non-magnetic material, such as a plastic crate.

- Ensure that you don't have a pen magnet or hand lens in your pocket, and move things like pencil cases, water bottles etc away from the frame.

- Make sure the core orienting frame is a workable distance from the steel racking, core shed etc. This doesn't have to be a mile down the paddock. Commonly, 8-10m from simple racking and core shed framework is more than enough. Don't go setting the frame up between the core racks. If you're worried – test it with your compass and see where/if needle deviation occurs.

- Check your rocks to make sure they don't have magnetic minerals in them.

Some useful references and information sources

The following is a short list, but more information can be obtained by reviewing references therein, or going to the information sources. Note that detailed treatment of how to work with oriented core is given in my **Olinda Gold structural geology course**, including copious references.

The references below might seem a bit dated, but the fundamentals have not changed. Rather, it is the sophistication of core orientation devices and electronic alpha-beta logging equipment that has improved. The audit process remains the same and the implications of failing to use the correct equipment, of avoidance of detailed QAQC on core orientation quality, of arrogantly assuming alpha-beta devices are all that are needed, of failing to establish structural populations, of biasing databases toward moderate to high alpha angle structures by failing to measure low alpha angle structures with alpha-beta devices, and of neglecting lineation measurement, still destroy value of mining and exploration projects. That said, here are a few references to get started with.

- Davis, B.K., 2014. Use and abuse of oriented drill core. Australasian Institute of Mining and Metallurgy (AusIMM), Monograph, 30, 121–136.

Still an industry standard, if I do say so myself!

- Davis, B.K., 2015. Innovations in electronic core orientation. The AusIMM Bulletin, June 2015. https://www.ausimmbulletin.com/feature/innovations-in-electronic-core-orientation/

Worth checking but then going to sites like Imdex to see the latest developments

- Davis, B.K., 2016. Oriented drill core - What we have learnt and where we are going? Coring Magazine, 2, pages 12-16.

A timely review at the time.

- Holcombe, R.J., 2016. Mapping and structural geology in mineral exploration: where theory hits the fan. HCOV Global. 233 pages.

One of the best comprehensive treatments of oriented core and structural mapping around.

Some concluding comments

These comments are based on a multitude of discussions in my structural geology course, on exploration sites, at mines, and on LinkedIn.

- Geologists who use a core orienting frame very commonly also use alpha-beta devices. They tend to do whatever is fit for purpose. And these geologists will be cross-checking both methods to review orientation data. Geologists who do production logging, or simply prefer alpha-beta devices, don't tend to use core orienting frames. I find this to be a distinct gap in the data collection and observation process, but there are a multitude of people who scream from high heaven to justify this.

- Non-electronic alpha-beta devices typically measure angles in 5-degree increments. This produces unrealistic data patterns, such as 'starfish' and 'bicycle spokes' on stereo plots.

- Different non-electronic alpha-beta devices are graduated in different directions and require zeroing of the device for measurement of beta from either the orientation line or the tip of ellipse. It is critical that the method is correct for the device and that the down-hole arrows on the device point in the correct direction. I've seen people scribbling out the information on the templates to try to make them work. This is not good!

- Electronic alpha-beta loggers:
    - Do not engender removal of core from the tray to critically review it (exceptions are when people want the kudos of being the first person to put a red circle around all the visible gold)
    - Measure structures exposed on the lower portion of the core surface (i.e. the surface containing the orientation line on the bottom side of the core). Features on the underside (structural top) of the core are not measured, nor are many of those exposed on core breaks.
    - Can massively over-collect data and bias statistical distributions. If you have an itchy trigger finger or a bit of a twitch, every click is a new 'data' point.
    - Commonly plot directly onto stereonets in real time. There is a tendency to delete data that doesn't fall with the dominant orientation population, because they 'don't fit', rather than pulling the core out of the tray and trying to resolve the disparity. The different orientations are commonly the important ones.
    - Are like many alpha-beta devices and struggle to measure features with low alpha angles. Once again, the high-heaven shriekers will say that isn't true and that they project the lines etc etc. However, in reality, the likelihood of people doing this is somewhere around that of getting your money back from a Kosovan scammer.
    - Should only be employed in conjunction with mandatory use of a core orienting frame. This is my opinion, but the alpha-beta advocates will no doubt have a shopping list of reasons why they don't do this (mummy, it hurts; it takes too long; the frame is too far away when it's removed from the influence of the metal core racks and I hate walking; I don't know how to use a compass etc).

- Structural geological data collection should be done in context. It is not a waste of time to divide up your structural features into different populations, based on overprinting, and then measure them as such. If more than one set of structures belongs to the same population, it is easy to combine them. However, if the individual populations are not defined at the start, and are lumped, then it is typically impossible to separate them later. One consultant understanding nothing tectonic, who worked on a major deposit at the same time as me, didn't understand the concept of different structure types (shear zones, faults, veins, cleavages etc) and told another colleague external to the project that I had compiled 26 fabrics! Actually, it was 26 different vein, alteration, dyke, metamorphic, structural events and fabrics – not a huge number in a massive, multiply reactivated permeability system. Don't be like this guy!

- Structures can be divided into planar and linear entities, and combinations thereof (gender is not the only thing that is fluid). Both are important!! However, linear structures are overwhelmingly under-represented in databases, despite the common strong linear control to mineralised volumes. Lineations are really hard to measure with alpha-beta devices, except on planar core breaks! And, if we are not taking the core out of the trays, which is common practice in production logging, we can't be sure of the apparent plunge of the lineations. So, internal lineations simply get ignored most of the time and linear controls are largely inferred from grade trends in 3D models that are commonly put together by people who haven't even gone to site. Measure more lineations! And do it from core, not your armchair in front of your monitor in your air-conditioned inner-city office.

- There is a tendency to include low quality structural data from oriented core. The data should be helping to constrain orebody geometries, as should the assays. If we only accept high quality assays, why do we accept medium and low-quality structural data?

- Finally, always check your equipment. Dynamics G-Ex makes one of the best frames on the market, but even they got caught out in 2023. When their carpenter died, the replacement worker was unaware of the necessity to use non-magnetic material in construction of a batch of core frames that were released to the public. I became aware of this when I checked a new Dynamics G-Ex frame being used at a client's exploration site. The frame is pictured below, with my pen magnet attached. The impact of the steel in this device was significant, as shown in the photos of the compass. The needle varies by between 20 and 40 degrees from true magnetic orientation to that against the frame. So, go and check your frames now, regardless of manufacturer. And if they are magnetic, do a review of the data and consequences. And full credit to Dynamics G-Ex – they owned the mistake and went into immediate damage control to rectify the situation.