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## Supplementary Material (1) for Xiaodong Qin et al.:

### GROT: A new rotation file format for GPlates

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#### Introduction

GPlates and the GPlate Geological Information Model (GPGIM) and the GPlates markup language (GPML) have opened new ways of working with plate tectonic data. Whereas the feature-centric data model has been vastly improved, the way the rotation model data is handled has not changed since the early days of the PLATES software. There is, however, a need to enhance the “richness” of the rotation file in terms of metadata, bibliographic annotation, revision

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histories and integration of rotation uncertainty estimates. I propose to model this new standard on the currently implemented GMT OGR format and a Multimarkdown-type set of attributes which should allow for an easy, streamlined processing in tools such as awk, Python or simple shell scripts as well as integration of these enhanced features into the GPlates software.

### *Commented lines in current rotation files*

Previously rotation files only allowed comments if they were denoted as 999 rotations. This is error prone as already pointed out during the early phases of the GPlates development and cumbersome when directly working with rotation files in a text editor.

999 rotations to comment out lines

An example of a commented line using the current practice of replacing the Plate ID of the moving plate with a 999 to disable it. The inactive rotation sequence data looks like this:

---

```
999 200.00 -55.810 -41.520 101.880 802 ! FLI-ANT Norton & Sclater 1979 fit
```

---

This method has the severe disadvantage, that the original plate ID (PlateID<sub>1</sub>, moving plate) is lost when inserting a comment. Secondly the comment area is not structured well enough for automatic processing, e.g. extracting bibliographic references related to individual rotations or groups of rotations. It is quite easy to conceive that simple file exchange in collaborations or the omission of metadata can lead to a significant loss of important information contained in the rotation file. In addition, the introduction of novel methods, such as deformation, or Hellinger-style rotation uncertainty parameters requires a much larger set of rotations to be dealt with.

### *The GPlates rotation file format – \*.grot*

The new GPlates rotation file format encapsulates important rotation metadata in a simple and logical way. It emulates various language syntaxes such as GMT OGR, MultiMarkdown, L<sup>A</sup>T<sub>E</sub>X Python and XML to provide a clean, logical and easy-to-use metadata framework. The file suffix for the new rotation file format is \*.grot for GPlates **rotation** file, pronounced g-rot (and not grot...).

The new file format uses \*.grot as extension

### *The \*.grot syntax: Basic features*

The following section outlines the proposed new standard for encoding metadata (essentially everything beyond the mandatory

Please comment or send feedback to Christian Heine (<mailto:christian.heine@sydney.edu.au>)

rotation parameters) which is backward-compatible, and machine-digestible. Please send comments or feedback to Christian Heine (mailto:christian.heine@sydney.edu.au).

### *Flags: Comments and moving plate rotation sequences*

Two new flags are introduced in the new \*.grot rotation file format:

---

```
# for commenting lines out
> denoting moving plate rotation sequences
```

---

**Flags:** # for comments and > for denoting moving plate rotation sequences

Lines starting with # and followed by text are ignored by GPlates unless they contain marked @ATTRIBUTE data. If the # is followed by a valid rotation pole specification, the line will be read by GPlates but the rotation pole itself will be disabled (inactive). In the new file format commented lines and comments would appear as:

---

```
# Comment which is ignored by GPlates
@C"Comment which is read by GPlates and associated with the next rotation pole below"
288 200.00 -55.81 -41.52 101.88 802
#288 200.00 -55.81 -41.52 101.88 802 @C"Comment read by GPlates but DISABLED rotation"
```

---

Lines starting with # and followed by text are *ignored* by GPlates

Lines starting with # and followed by a valid rotation pole specification are regarded *disabled/inactive* by GPlates

For legacy applications using rotation files a simple awk one-liner using RegEx can be used strip off all commented lines or simply precede them by a 999 0.0 0.0 0.0 0.0 999 # rotation line.

A new **Moving Plate Rotation Sequence (MPRS)** is introduced in this version of the rotation file. The MPRS serves as header or “segment” and follows the idea of “bookmarking” individual blocks of rotation sequences in various text editors as well as in GPlates as well as the concept of multi line segments in GMT. Detailed info on the syntax of the MPRS in Sec. *Moving Plate Rotation Sequence (MPRS) header*.

Moving Plate Rotation Sequences (**MPRS**) are all rotations applying to an individual moving plate, including cross overs

---

```
> @MPRS:pid"002" @MPRS:code"PHS" @MPRS:name"Pacific Hotspots"
002 0.780 49.3000 -49.500 -1.020 901
002 2.580 53.7200 -56.880 -2.660 901
002 5.890 59.6500 -66.050 -5.390 901
002 8.860 62.8700 -70.870 -8.230 901
```

---

### *Standardised metadata attribute/value format*

Metadata attributes recognised by GPlates in the new format have a specific format. They are prefixed by an “@” symbol followed by a text string which is the name of the attribute. The attribute value is

@ATTRIBUTE"VALUE" is the basic metadata format

enclosed in a pair of double quotes `""`. The allowed set of keywords is listed completely in Sec. "Attribute List".

---

```
@ATTRIBUTE"VALUE"
```

```
@AU"CHHEI"
```

---

The syntax allows to have multiple fields for the Value. These fields must be separated by vertical bars/pipes without whitespace before or after the attribute (akin to GMT OGR):

Attribute Values can have *multiple fields*

---

```
@ATTRIBUTE"Value 1 | Value 2 | Value 3"
```

```
@MPRS"101|NAM|North America"
```

---

The following variations for the different attribute:value pairs are allowed, depending on the complexity of the original attribute:

Attributes can have (nested) child attributes

---

```
@ATTRIBUTE:subattribute"Value"
```

```
@MPRS:name"North America"
```

```
@MPRS:pid"101"
```

```
@MPRS:code"NAM"
```

---

Attribute and subattributes allow nesting at deeper levels. Consider the following example:

Nested attributes can be written in compact or verbose forms

---

```
# Template
```

```
@ATTRIBUTE:subattribute:subsubattribute"Value"
```

```
# Compact version
```

```
@DC:contributor"JOCA|John Cannon|john.cannon@sydney.edu.au"
```

```
# Extended version
```

```
@DC:contributor:name"John Cannon"
```

```
@DC:contributor:id"JOCA"
```

```
@DC:contributor:email"john.cannon@sydney.edu.au"
```

---

Here, one complex set of subattribute and subsubattributes can be combined in one line or listed separately in sequence on individual lines.

### *Attribute aliases and external structures*

This method also allows the creation of *aliases* which can be created by referencing certain fields to reduce complexity of nested parent:children attributes. In the current version the use of user-defined

Nested attributes can be *aliased*

aliases is not supported. Example:

User-defined aliases are not supported at present

---

```
#Template
@ATTRIBUTE:subattribute"ID | Name | Email"

# Header info
@DC:contributor"JOCA | John Cannon | john.cannon@sydney.edu.au"
@DC:contributor"MCHIN | Michael Chin | michael.chin@sydney.edu.au"
@DC:contributor"CHHEI | Christian Heine | christian.heine@sydney.edu.au"

# This creates an alias
# However, user-defined aliases are not supported currently!
alias @AU = @DC:contributor:id

# Use alias in rotation sequence
@AU"JOCA"
@AU"CHHEI"
@AU"MCHIN"
```

---

In this example, an attribute and subattribute (DC:contributor) contains a list of values, all separated by a vertical bar/pipe. These attribute values conform to a standardised list where the first element is a unique Author ID, the second specifies the real world name of this author and the third his email. The attribute alias can now be created by assigning the @AU attribute a list of possible values which are all derived from all available DC:contributor"ID" fields.

This setup allows even to fetch complex structures from external files. Say we keep a BibTeX bibliographic database along with our rotation file. In this file, bibliographic data is collected, with each entry having a unique identifier (the so-called citekey). Using nested attributes and aliases we are able to create the following setup:

Attributes can reference external sources

---

```
# Header
@BIBINFO:bibliographyfile"file://rotationfile.bib"

# Alias
alias @REF = @BIBINFO:bibliographyfile:citekey

# Actual rotation metadata
@REF"Heine.AGU-GM.04"
```

---

This creates the possibility to relatively link unique elements from one source into the rotation file by direct mapping of this unique identifier. A possibly query would yield the BibTeX record for the citation key "Heine.PEPL.o8" in the associated bibliographic data file which was specified in the header record using the @BIBINFO:bibliographyfile attribute.

Another application is the **possibility of spatial queries** by referencing certain feature types in an associated GPML file or a remote data source. Consider the following example:

Attributes can be used to generate spatial queries

---

```
# Header
@GPML:namespace"http://www.earthbyte.org/Resources/GPGIM/public/"

# Alias
alias @CHRONID = @GPML:MagneticAnomalyIdentification:polarityChronID

# Rotation
101 33.100 75.9900 5.9800 9.770 714 @CHRONID"C13"
```

---

With the available information, GPlates can go and run a spatial query to extract all the relevant features from a source file (e.g. a GPML file with all magnetic anomaly picks). The query would look like:

---

```
Find all C13 picks on plate ID 101 which have a conjugate plate id 714
```

---

Naturally, a magnetic anomaly picking scheme has to be agreed upon or explicitly stated in the CHRONID (e.g. the young end of C13–C13y). As the GPGIM specification states, this information should be included in the value part of this attribute. Refer to <http://www.earthbyte.org/Resources/GPGIM/public/#PolarityChronId> for details. Such a geospatial query can be run for all applicable features.

Currently supported aliases are:

- CHRONID --> GPML:MagneticAnomalyIdentification:polarityChronID
- AU --> DC:contributor:id
- REF --> BIBINFO:bibliographyfile:citekey
- DOI --> BIBINFO:doibase:doi
- GTS --> GEOTIMESCALE:id

### *File structure*

The new rotation file format is subdivided into two parts:

\*.grot Files have a *Header* and *Body*

1. a file header containing metadata and global definitions used in the rotation sequences (Sec. *File header*)
2. the rotation sequence body (Sec. *File body*), composed of individual moving plate rotation sequences (MPRS) which are in turn composed of lines containing rotation data (adhering to the basic PLATES rotation file syntax)

*File header [mandatory]*

New GPlates rotation files have a mandatory file header which must be present in all rotation files. The file header contains important information on how to processes different parts of the file and also carries important metadata, such as information on the Geological Time Scale used for rotations. Apart from the mandatory metadata in the header, there are also optional blocks which allow the user to put revision information or any other data the user finds necessary. Future version of GPlates (> 1.3) will include the opportunity to edit this information through a GUI.

The file header contains global meta-data which are referenced in the file body. It adheres to specific format and contains mandatory attributes

The file header follows the core elements of the Dublin Core metadata initiative which specifies 15 standard tags to identify electronic documents (see <http://dublincore.org/documents/dcmi-terms>).

Let's start out with the mandatory information in the file header, here's the overview:

**ROTATION FILE VERSION**

The first line uses the `@GPLATESROTATIONFILE:version"xx"` attribute to specify that this file adheres to the new rotation file standard and gives the current rotation file version number.

`@GPLATESROTATIONFILE:version` — File format versioning

`@GPLATESROTATIONFILE:version` — File format versioning

---

```
@GPLATESROTATIONFILE:version"1.0"
```

---

**DUBLIN CORE DOCUMENT INFORMATION**

The subsequent attributes use the `@DC` parent attribute to denote a set of Dublin Core metadata describing the file content. This also includes links to licenses, modification dates and proper citations for the file. See the complete list and explanation of the header attribute data in *Sec. Header attribute list*.

`@DC` — document metadata

---

```
@DC:namespace"http://purl.org/dc/elements/1.1/"
@DC:title"GPlates rotation file - NEW ROTATION FORMAT SAMPLE FILE"
@DC:creator:name"Christian Heine"
@DC:creator:email"mailto:christian.heine@sydney.edu.au"
@DC:creator:url"http://www.gplates.org"
@DC:creator:affiliation"EarthByte Research Group, School of Geosciences"
@DC:creator:affiliation"The University of Sydney, NSW 2006, Australia"
@DC:rights:license"Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0)"
@DC:rights:url"http://creativecommons.org/licenses/by-nc-sa/3.0/"
@DC:date:created"2/06/11 4:08:05 PM"
@DC:date:modified"$Date: 2012-05-14 08:15:28 +1000 (Mon, 14 May 2012) $"
@DC:coverage:temporal"0-600 Ma"
@DC:bibliographicCitation""Chin, Mueller, Cannon, Landgrebe, Heine,
                        Watson, Turner (2012) The GPGIM vol:pp-pp,
                        J. Digital Earth. doi:xxxxxxxxx ""
@DC:description""
```

---

A sample rotation file in the new GPlates rotation file format v1.1

Based on moving Indian/Atlantic hotspots (O'Neill et. al. 2005)  
to 100 Ma and true polar wander corrected palaeomagnetic  
reference frame (derived from Steinberger and Torsvik 2008)  
from 100 - 200 Ma. 250 Ma is the extent of this rotation model.  
Pacific absolute reference frame based on Wessell and Kroenke 2008  
with a switch to Wessel et. al. 2006 at 118.4 Ma  
Reference for rotation model: Seton et. al. (submitted to ESR)""

---

## CONTRIBUTING AUTHORS

The next mandatory block is the contributor information related to individuals who have worked on various parts of the rotation sequences. In order to correctly attribute contributions which have not made it into publications, this section lists authors with their contact details and full name. The lines use the @DC:contributor form of the Dublin Core specifications and the value field contains multiple values. In most cases, especially in intra-institutional use, not all rotations are published in the form of a citable reference, enlisting contributing authors still provides a reference to the creator.

@DC:contributor — Contributing authors

---

```
# Template
@DC:contributor"id | Real Name | Email | URL | [Postal address, other contact details]

# Example (single line)
@DC:contributor"RDM | R. Dietmar Muller | dietmar.muller@sydney.edu.au | \
  http://www.earthbyte.org | EarthByte Group, The University of Sydney, Australia"

# Example (multi line)
@DC:contributor""CHHEI |
  Christian Heine |
  christian.heine@sydney.edu.au |
  http://www.earthbyte.org |
  EarthByte Group, School of Geosciences, The University of Sydney
```

---

## BIBLIOGRAPHIC AND REFERENCE SECTION

The next mandatory block encompasses the bibliographic or reference data valid for the file globally. The field contain a reference to a bibliographic data base in BibTeX format (see Sec. *Bibliographic data*) as well as to the GPlates Information Model (GPGIM) website and a base URL for the Digital Object Identifier (DOI). All these attribute will be referenced from the individual MPRS or rotations.

@BIBINFO — Optional inclusion of bibliographic databases

The inclusion of mandatory bibliographic reference data allows a future use of GPlates in conjunction with hyperlinks (through the DOI) to a publication as well as direct links to a bibliographic companion database file:



```
@BIBINFO:bibfile"file://rotationfile_v2.bib"
@BIBINFO:doibase"http://dx.doi.org/"
@GPML:namespace"http://www.earthbyte.org/Resources/GPGIM/public/"
```

---

## GEOLOGICAL TIME SCALES

One of the most important piece of metadata is information about the geological time scales (GTS) used to convert relative geological ages to absolute times. These GTS constantly evolve and a Base Aptian on some timescale from the 1990's has a few Million Years difference to a Base Aptian from the 2010's. The GTS are listed in the header section and are referenced through a tag at individual rotation level.

@GEOTIMESCALE — Mandatory inclusion of Geological Time Scales

---

```
# Template
@GEOTIMESCALE" ID | DOI/URL/ISSN (specify) | CiteKey | Bibliographic record/Comment"

# Multiline specification of GTS
@GEOTIMESCALE"" GEEK07 |
    doi:10.1016/B978-044452748-6.00097-3 |
    Gee.ToC.07 |
    Gee, J.S. and Kent, D.V. (2012) 5.12 - Source of Oceanic \
Magnetic Anomalies and the Geomagnetic Polarity Timescale, in: Treatise on\
Geophysics, Volume 5, Pages 455--507, Elsevier, Amsterdam""
#
@GEOTIMESCALE"" CK95G94 |
    doi:10.1029/94JB03098; doi:10.1029/94JB01889 |
    Cande.JGR.95; Gradstein.JGR.94 |
    S. C. Cande and D. V. Kent. Revised Calbration of the\
geomagnetic polarity timescale for the Late Cretaceous and Cenozoic. \
J. Geophys. Res., 100(B4):6093--6095, 1995.;
    F. M. Gradstein, F. P. Agterberg, J. G. Ogg, J. Hardenbol, P. van Veen,\
J. Thierry, and Z. Huang. A Mesozoic time scale. J. Geophys. Res.,\
99:24051--24074, 1994. doi:10.1029/94JB01889.""
#
@GEOTIMESCALE"" Absolute
    |
    |
    Absolute numerical time in Ma""
```

---

## OPTIONAL: REVISION HISTORY

The optional revision history block is used for versioning. The actual list of applicable subattributes depends on the versioning system used. Each Keyword should be shortened and prefixed by @REVISIONHIST[keyword]"value". Example for a Subversion repository setup:

@REVISIONHIST — Optional inclusion of versioning information

---

```
@REVISIONHIST"$Id: CHHEI_RotFileStd.tex 1796 2012-05-13 22:15:28Z christian $"
```

---

*File body: The rotation sequences*

The file body contains all Moving Plate Rotation Sequences (MPRS) which are in turn composed of individual lines listing rotation parameters.

## MOVING PLATE ROTATION SEQUENCE (MPRS) HEADER

The moving plate rotation sequence (MPRS) specifies a block of rotations which all have the same moving plate id. It is denoted by a > flag at the start of each line and allows multi-line headers. The introduction of a header for any moving plate rotation sequence follows the idea that most metadata is applied to a whole sequence of rotations and allows for better “bookmarking” in GPlates’ rotation file editor or other external text editors. The rotation header sequence denominator is modelled as follows:

@MPRS — The Moving plate rotation sequence

---

```
# Template
> @MPRS:pid"PID1" @MPRS:code"XXX" @MPRS:name"Moving Plate name"

# Compact version
> @MPRS"288 | FLI" | Falkland Islands"

# Extended version
> @MPRS:pid"288" @MPRS:code"FLI" @MPRS:name"Falkland Islands" @C"optional comment"

# Multiline version
> @MPRS:pid"288"
> @MPRS:code"FLI"
> @MPRS:name"Falkland Islands"
> @C"Optional comment" @AU"CHHEI"
```

---

Oftentimes the full moving plate rotation sequence is taken from a single author/publication. In that case, adding metadata to each rotation line would increase the possibility for mistakes. The new rotation file format allows the user to specify metadata for a whole MPRS in the header which then applies to all rotations in that sequence:

>@MPRS — Default metadata for individual rotations

---

```
> @MPRS:pid"002" @MPRS:code"PHS" @MPRS:name"Pacific Hotspots"
002 2.580 53.7200 -56.880 -2.660 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 5.890 59.6500 -66.050 -5.390 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 8.860 62.8700 -70.870 -8.230 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 12.290 65.3700 -68.680 -10.300 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 17.470 68.2500 -61.530 -15.500 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 24.060 68.7800 -69.830 -20.400 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 28.280 67.7200 -70.800 -23.600 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 33.540 66.5700 -68.730 -27.700 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
002 40.100 65.4300 -64.250 -31.600 901 @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"GeeK07"
```

---

can now be replaced with

---

```
> @MPRS:pid"002" @MPRS:code"PHS" @MPRS:name"Pacific Hotspots"
> @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"Geek07"
002 2.580 53.7200 -56.880 -2.660 901
002 5.890 59.6500 -66.050 -5.390 901
002 8.860 62.8700 -70.870 -8.230 901
002 12.290 65.3700 -68.680 -10.300 901
002 17.470 68.2500 -61.530 -15.500 901
002 24.060 68.7800 -69.830 -20.400 901
002 28.280 67.7200 -70.800 -23.600 901
002 33.540 66.5700 -68.730 -27.700 901
002 40.100 65.4300 -64.250 -31.600 901
```

---

In case there are changes to individual rotations in the MPRS these can be done on line/rotation pole level and will override the MPRS header data:

Multiline comment metadata in @MPRS header

---

```
> @MPRS:pid"002" @MPRS:code"PHS" @MPRS:name"Pacific Hotspots"
> @PP"PHS-PAC" @REF"Wessel.JGR.08" @C"Model WK08-A" @GTS"Geek07"
002 2.580 53.7200 -56.880 -2.660 901
002 5.890 59.6500 -66.050 -5.390 901
002 9.0 62.8700 -70.870 -8.230 901 @AU"CHHEI" @T"2012-05-03" @C"Changed time from 8.860"
002 12.290 65.3700 -68.680 -10.300 901
002 17.470 68.2500 -61.530 -15.500 901
002 24.060 68.7800 -69.830 -20.400 901
002 28.280 67.7200 -70.800 -23.600 901
002 33.540 66.5700 -68.730 -27.700 901
002 40.100 65.4300 -64.250 -31.600 901
```

---

Given the above, the new 9.0 Ma rotation will carry the metadata specified on for the individual pole and *only the specified pole metadata overrides the MPRS metadata* (non-overridden metadata is still inherited from the MPRS).

#### ROTATION LINE DATA

We adopt the legacy PLATES rotation format which consists of 6 mandatory parameters specifying the stage pole of any given rotation. The format has not changed and is fully compatible with legacy applications.

Backwards compatibility with PLATES rotation data

---

```
PID1 STARTAGE POLELAT POLELON ANGLE PID2
```

---

PID1 Plate ID 1 (moving plate)

FROMAGE Excuse the french. Start age.

PLAT Rotation pole latitude

---

GPlates rotation File Format Specification

Version 1.0

PLON Rotation pole longitude

ROTANGLE Rotation pole angle

PID2 Fixed Plate, plate ID 2

New optional meta data attributes from the dictionary can be added to the individual lines. The optional attributes follow the structure layed out in Sec. *Attribute format* and can consist of the following elements:

Rotation metadata attributes

@PP| Abbreviated description of the relative plate motions, e.g. Africa-South America to @PP"SAM-AFR", the abbreviated names have to adhere to the @MPRS:code from the MPRS.

@C Free form comment

@GTS:id Unique ID of the geological time scale used in identifying the magnetic anomaly picks. References the GEOTIMESCALE:id in the file header

@AU Abbreviation/ID of modification author. *Alias* which references DC:contributor:id in the file header.

@DOI Digital object identifier for reference related to that individual rotation. *Alias* to @BIBINFO:doibase:doi.

@REF Citation key for reference related to that individual rotation. *Alias* for @BIBINFO:bibliographyfile:citekey.

@HELL set of attribute:value pairs for uncertainty parameters for this rotation. For details see Sec. *Uncertainty parameters*.

@T Modification date/time. Adhere to ISO standard (ie [YYYY]-[MM]-[DD]T[hh]:[mm]:[ss]).

@CHRONID Magnetic anomaly chron ID. *Alias* to GPML:MagneticAnomalyIdentification:polarityChronID and adheres to strict naming convention. The identifier used for magnetic picks evolved to be a combination of letters and numbers, of the form

---

(C/M)<number><combination of letters>

---

See <http://www.earthbyte.org/Resources/GPGIM/public/#PolarityChronId> for details.

Example:

---

```
833 53.300 -14.1900 130.4100 -0.7200 801 @PP"LHR-AUS" @DOI"10.1029/98JB00386" @CHRONID"C240"
```

---

*Uncertainty data for rotations*

The Hellinger method allows to compute statistical uncertainties for rotations, representing them as a series of parameters and a 3D-covariance matrix.

Hellinger Statistics attributes for individual rotations

These parameters are:

$r$  total misfit (sum of squares of the weighted distances of data points to great circle segment) in [km]

$N$  number of data points

$s$  number of great circle segments

$dF$  number of degrees of freedom

$\hat{\kappa}$  kappahat, quality factor which relates the uncertainties assigned to the data to their true estimates

- a  $3 \times 3$  covariance matrix which needs to be divided by the factor kappahat to convert in square radians

An example matrix is given here obtained from the file satl.34 and running the hellinger1 program:

$$\begin{pmatrix} 8.71113084 & -4.33230877 & -4.97091355 \\ -4.33230877 & 4.01436998 & 3.23033819 \\ -4.97091355 & 3.23033819 & 3.6493551 \end{pmatrix} \times 10^{-7} \quad (1)$$

So far, Hellinger-fit criteria have not been explicitly expressed in the rotation file. For the new standard, the Hellinger statistics need to be included explicitly in the format expressed below. The complete Hellinger values can either be represented as coherent string with the some matrix values omitted due to the rotational symmetry of the matrix:

@HELL" r | (N, s) | dF | kappahat | (( $x_1$ ,  $x_2$ ,  $x_3$ ) ( $y_2$ ,  $y_3$ ) ( $z_3$ )) "

or as a separate set of arguments using the @HELL Parent:Children attributes:

@HELL: r total misfit

@HELL: Ns number of data points and segment length

@HELL: dF number of degrees of freedom

@HELL: kappahat Quality factor  $\hat{\kappa}$

@HELL: cov Covariance matrix, here we ONLY USE (( $x_1$ ,  $x_2$ ,  $x_3$ ) ( $y_2$ ,  $y_3$ ) ( $z_3$ )) due to the rotational symmetry of the matrix used.

Example:

---

```
# Multi line version
@HELL:r"41.1911338"
@HELL:Ns"75,16"
@HELL:dF"40."
@HELL:kappahat"0.971082763"
@HELL:cov"(8.71113084E-07,-4.33230877E-07,-4.97091355E-07) \
          (4.01436998E-07,3.23033819E-07)(3.6493551E-07)"

# Compact single line
@HELL"41.1911338 |75,16 | 40.| 0.971082763|\
 (8.71113084E-07,-4.33230877E-07,-4.97091355E-07) \
 (4.01436998E-07,3.23033819E-07)(3.6493551E-07)"
```

---

### *Bibliography information*

Each rotation file should come with a companion bibliographic reference database in the ascii-based BibTeX format (<http://www.bibtex.org/Format/>). The choice for BibTeX is driven by the fact that the format is text-based, accepted as one of the bibliographic data standards and many software tools allow to either directly use this format (BibDesk, JabREF) or import/export it (e.g. Endnote). At a future data the bibliographic information can possibly be incorporated consistently into the rotation file format without the need for two separate files.

Companion BibTeX databases

### *Online resources*

- GPlates web site: <http://www.gplates.org>
- BibTeX resources: <http://www.bibtex.org/>
- Info about Dublin Core: [http://en.wikipedia.org/wiki/Dublin\\_Core](http://en.wikipedia.org/wiki/Dublin_Core)

### *Attribute list*

#### *Header attribute list*

All Dublin Core elements are prefixed with a "DC".

@GPLATESROTATIONFILE Mandatory: Declaration of file type

@ = :version Written by GPlates: Declaration of file version number.

@ = :documentation Written by GPlates: URL of standard specification (this document).

<code>@DC:namespace</code> Mandatory: Dublin Core Elements RDF schema link. Value: "http://purl.org/dc/elements/1.1/".	<code>@DC:namespace</code>
<code>@DC:title</code> Title of the document, e.g. "GPlates rotation file - NEW ROTATION FORMAT SAMPLE FILE".	<code>@DC:title</code>
<code>@DC:creator:name</code> Mandatory: Name of the creator of the document. Multiple occurrences of attribute allowed. Example: "Christian Heine".	<code>@DC:creator:name</code>
<code>@DC:creator:email</code> Mandatory: Email of the document creator. Multiple occurrences of attribute allowed. Example: "christian.heine@sydney.edu.au".	<code>@DC:creator:email</code>
<code>@DC:creator:url</code> Mandatory: URL related to creator such as homepage. Multiple occurrences of attribute allowed. Example "http://www.earthbyte.org/people/christian".	<code>@DC:creator:url</code>
<code>@DC:creator:affiliation</code> Mandatory: Affiliation of creator, such as Institute, postal address, phone. Multiple occurrences of attribute allowed. Example: "EarthByte Research Group, School of Geosciences".	<code>@DC:creator:affiliation</code>
<code>@DC:rights:license</code> Mandatory: Appropriate licensing terms for the data included in the file. Example: "Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0)".	<code>@DC:rights:license</code>
<code>@DC:rights:url</code> Mandatory: URI of licensing terms for the data. Example: "http://creativecommons.org/licenses/by-nc-sa/3.0/".	<code>@DC:rights:url</code>
<code>@DC:date:created</code> Mandatory: Creation date of document, follow ISO standard (ie [YYYY]-[MM]-[DD] T[hh]:[mm]:[ss]). Example "2011-06-01T09:08:05".	<code>@DC:date:created</code>
<code>@DC:date:modified</code> Optional: Latest modification date of document. Multiple occurrences of attribute allowed. Can hold revision date if under revision control. Example "Date: 2012-05-08 16:55:58 +1000 (Tue, 08 May 2012)".	<code>@DC:date:modified</code>
<code>@DC:coverage:temporal</code> Optional: Temporal coverage of data included in this file. Example "0-600 Ma".	<code>@DC:coverage:temporal</code>
<code>@DC:bibliographicCitation</code> Optional: Full, plain text bibliographic citation for the current file. Example: "Mueller, R.D. and Seton, M. and Roest, W. (2008): Global. Geochem., Geophys., Geosys. xx:".	<code>@DC:bibliographicCitation</code>
<code>@DC:description</code> Mandatory: Description of data set contained in this file. Multiline comment wrapped in triple quotation marks """" (like in Python) are allowed, as are multiple occurrences of the attribute to mimick the same effect as for multiline value. Example: " A sample rotation file in the new GPlates rotation file format v1.1".	<code>@DC:description</code>

<p><b>@REVISIONHIST</b> Optional. Parent attribute for data which is under a revisioning system. User can generate child attributes by separating them with a colon (:) from the parent tag. Example: <code>@REVISIONHIST:id"rotationfile_v2.rot 1774 2012-05-08 06:55:58Z christian"</code>. See example rotation file.</p>	@REVISIONHIST
<p><b>@BIBINFO</b> Optional. Parent attribute for bibliographic reference data related to this rotation file.</p>	@BIBINFO
<p><b>@ = :bibliographyfile</b> Optional. URI for location of bibliographic reference data in BibTeX format. Example: <code>"file://rotationfile_1-0.bib"</code></p>	@BIBINFO:blibliographyfile
<p><b>@ = :doibase</b> Mandatory. URL for resolving DOIs used in the bibliographic data. Example: <code>"http://dx.doi.org/"</code>.</p>	@BIBINFO:doibase
<p><b>@GPML</b> Parent attribute for GPGIM-derived attributes.</p>	@GPML
<p><b>@GPML:namespace</b> Mandatory. URI for the location of the GPGIM Schema document. Currently: <code>http://www.earthbyte.org/Resources/GPGIM/stable/</code>.</p>	@GPML:namespace
<p><b>@DC:contributor</b> Mandatory: Author data attribute for every contributor to this file. Data needs to be split into at least 5 different fields separated by vertical bars ( ): <b>ID</b> — Unique ID for contributor (CHHEI), maps to @AU in rotation sequence comments; <b>Real Name</b> — of contributor (Christian Heine); <b>Email</b> — Email of contributor; <b>URL</b> — Website of contributor; Institute, Postal address, other contact details for contributor. Fields can be left blank.</p>	@DC:contributor
<p><b>@GEOTIMESCALE</b> Mandatory. Bibliographic data for individual time scales used. Data is split into <i>at least 3 fields</i>, separated by vertical bars ( ) and can extend over multiple lines using the triple quotation marks. These are 1) <b>ID</b> — unique ID of timescale to be used in the @GTS tag for the individual rotation sequences. 2) <b>DOI/URL/ISSN</b> — Unique identifier for publication the timescale is based upon, prefixing the actual values (like <code>doi:12.12312/991823</code>); 3) Plain text full <b>bibliographic reference</b> for timescale or comments.</p>	@GEOTIMESCALE
<p><i>Rotation sequence metadata</i></p>	
<p><b>@MPRS</b> Parent element for Moving Plate rotation sequence</p>	@MPRS
<p><b>@MPRS:pid</b> Mandatory. Moving Plate ID. Denotes the start of a block of rotations which all belong to a single moving plate. Example <code>@MPRS:pid"801"</code>.</p>	@MPRS:id
<p><b>@MPRS:code</b> Mandatory. Unique letter acronym (variable length) for a moving plate. Example <code>@MPRS:code"SAM"</code> for South America.</p>	@MPRS:code



@MPRS:name Mandatory. Unique full name for moving plate. Example: @MPRS:name"South America".	@MRPS:name
@PP Mandatory. Plate pair of moving plate–fixed plate as specified by plate IDs, allowed values can only be composed of valid @MPRS:code values. Example @PP"SAM-AFR" for rotations expressing the rotation between South America relative to Africa.	@PP
@REF Optional. Unique citation key of bibliographic data used for this rotation. Maps to entries specified in @BIBINFO:bibfile value.	@REF
@DOI Optional. Digital object identifier for bibliographic data used for this rotation. Maps to entries specified in @BIBINFO:doibase value for complete a valid URL.	@DOI – Alias
@AU Optional. Author of rotation sequence data, maps to first field of @DC:contributor, which is the unique contributor ID. Example: @AU' 'CHHEI' '.	@AU – Alias
@T Optional. Modification time stamp for rotation sequence data. Adhere to ISO standards in the for of YYYY-MM-DD [HH:MM:SS TZ ]. Example: "2012-05-04 10:30:22+10".	@T
@C Optional. Freeform comment.	@C
@GTS:id Mandatory. Geological time scale ID. Maps to first field of @GTS:info which is the unique identifier for the timescale used.	@GTS
@CHRONID Alias for Magnetic anomaly chrons as specified in GPGIM. References: @GPML:MagneticAnomalyIdentification:AnomalyPickID.	@CHRONID – Alias
@HELL Parent element for Hellinger statistical fit parameters.	@HELL
@HELL:r Total misfit.	@HELL:r
@HELL:Ns number of data points and segment length.	@HELL:Ns
@HELL:dF number of degrees of freedom.	@HELL:dF
@HELL:kappahat Quality factor $\hat{\kappa}$	@HELL:kappahat
@HELL:cov Covariance matrix, here we ONLY USE $((x_1, x_2, x_3) (y_2, y_3) (z_3))$ due to the rotational symmetry of the matrix used.	@HELL:cov

## Rotation file example

```

@GPLATESROTATIONFILE:version"1.0"
@GPLATESROTATIONFILE:documentation"http://www.gplates.org/grot/"
# ---- SUPPORTED ATTRIBUTE ALIASES
#
# CHRONID --> GPML:MagneticAnomalyIdentification:polarityChronID
# AU --> DC:contributor:id (Author)
# REF --> BIBINFO:bibliographyfile:citekey (Reference)
# DOI --> BIBINFO:doi:base:doi
# GTS --> GEOTIMESCALE:id
#
#-----+-----
# KEYWORDS | starting with ATTRIBUTE"Value" -- ALLOWS MULTIPLE VALUE FIELDS BY
#           | separating them with a | (vertical bar). Values can be enclosed in
#           | single quotes.
#           | PLEASE CONSULT http://www.gplates.org/grot/ for valid attributes
#-----+-----
# C         | Comment
# DC:subattr| DublinCore document description metadata (see documentation)
# GPML      | GPlates Markup Language Schema (can use GPML:FeatureType as subset)
# MPRS:pid  | Denotes Moving Plate ID
# MPRS:name | Moving plate full name
# MPRS:code | Moving plate letter code, usually 3-4 capital letters
# PP        | Plate pair with Plates denoted as letter acronyms separated by minus sign (-)
# T         | Modification date/time in YYYY-MM-DD [TZ HH:MM:SS]
#
# ---- FILE METADATA -----
#
@DC:namespace"http://purl.org/dc/elements/1.1/"
@DC:title"GPlates rotation file - NEW ROTATION FORMAT SAMPLE FILE"
@DC:creator:name"Christian Heine"
@DC:creator:email"mailto:christian.heine@sydney.edu.au"
@DC:creator:url"http://www.gplates.org"
@DC:creator:affiliation"EarthByte Research Group, School of Geosciences"
@DC:creator:affiliation"The University of Sydney, NSW 2006, Australia"
@DC:rights:license"Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0)"
@DC:rights:url"http://creativecommons.org/licenses/by-nc-sa/3.0/"
@DC:date:created"2/06/11 4:08:05 PM"
@DC:date:modified"$Date: 2012-05-14 08:15:28 +1000 (Mon, 14 May 2012) $"
@DC:coverage:temporal"0-600 Ma"
@DC:bibliographicCitation""Chin, Mueller, Cannon, Landgrebe, Heine,
      Watson, Turner (2012) The GPGIM vol:pp-pp,
      J. Digital Earth. doi:xxxxxxx""
@DC:description""
A sample rotation file in the new GPlates rotation file format v1.1

Taken from the current GPlates release rot file
Based on moving Indian/Atlantic hotspots (O'Neill et. al. 2005)
to 100 Ma and true polar wander corrected palaeomagnetic
reference frame (derived from Steinberger and Torsvik 2008)
from 100 - 200 Ma. 250 Ma is the extent of this rotation model.
Pacific absolute reference frame based on Wessell and Kroenke 2008
with a switch to Wessel et. al. 2006 at 118.4 Ma""
#
# ---- REVISION HISTORY INFORMATION -----
#
@REVISIONHIST"$Id: rotationfile.1-0.grot 1796 2012-05-13 22:15:28Z christian $"
#
# ---- BIBLIOGRAPHIC AND DATA REFERENCE INFORMATION -----
#
@BIBINFO:bibfile"file://rotationfile_v2.bib"
@BIBINFO:doi:base"http://dx.doi.org/"
@GPML:namespace"http://www.earthbyte.org/Resources/GPGIM/public/"
#
# ----- AUTHOR INFORMATION -----
#
@DC:contributor"RDM | R. Dietmar Muller | dietmar.muller@sydney.edu.au | http://www.earthbyte.org | Geosciences, The University of Sydney, Australia"
@DC:contributor"MS | Maria Seton (Sdrolias) | maria.seton@sydney.edu.au | http://www.earthbyte.org | Geosciences, The University of Sydney, Australia"
@DC:contributor"CG | Carmen Gaina | carmen.gaina@fys.uio.no | http://www.geodynamics.no | University of Oslo, Norway"
@DC:contributor"CHHEI |
      Christian Heine |
      christian.heine@sydney.edu.au |
      http://www.earthbyte.org |
      EarthByte Group, School of Geosciences, The University of Sydney, Australia""
@DC:contributor"CRS | Christopher R. Scotese | | | UT/Paleomap Project"
@DC:contributor"LAL | Larry A. Lawver | | | UTIG PLATES Project"
@DC:contributor"IWD | Ian W. Dalziel | | | UTIG PLATES Project"
@DC:contributor"LMG | Lisa M. Gahagan | | | UTIG PLATES Project"
@DC:contributor"DN | Dirk Nuernberg | | | CAU-Kiel University, Germany"
@DC:contributor"EBYTE | EarthByte Group | | http://www.earthbyte.org | School of Geosciences, Sydney Uni"
@DC:contributor"THT | Trond Helge Torsvik | Trond.Torsvik@fys.uio.no | http://www.geodynamics.no | PGP, University of Oslo, Norway"
#
#---- GEOLOGICAL TIME SCALE INFORMATION -----
#
@GEOTIMESCALE"" GeeK07 |
      doi:10.1016/B978-044452748-6.00097-3 |
      Gee.ToC.07 |
      Gee, J.S. and Kent, D.V. (2012) 5.12 - Source of Oceanic Magnetic
      Anomalies and the Geomagnetic Polarity Timescale, in: Treatise on
      Geophysics, Volume 5, Pages 455&A5507, Elsevier, Amsterdam""
@GEOTIMESCALE"" CK95G94 |
      doi:10.1029/94J0803098; doi:10.1029/94J081889 |
      |
      S. C. Cande and D. V. Kent. Revised Calibration of the geomagnetic
      polarity timescale for the Late Cretaceous and Cenozoic. J. Geophys.
      Res., 100(B4):6093&A6095, 1995;
      F. M. Gradstein, F. P. Agterberg, J. G. Ogg, J. Hardenbol, P. van Veen,
      J. Thierry, and Z. Huang. A Mesozoic time scale. J. Geophys. Res.,
      99:24051&A24074, 1994. doi:10.1029/94J081889.

```

```

****
@GEOTIMESCALE"" Absolute
|
| Absolute numerical time in Ma""
# -----
# --- END ROTATION FILE HEADER -----
#
# This comment will be ignored by GPlates
> @MPRS:pid"001" @MPRS:code"AHS" @MPRS:name"Present day Atlantic-Indian hotspots" @PP"AHS-HOT"
> @C"This comment will be read by GPlates and will appear at Moving plate rotation sequence level"
001 0.000 0.0000 0.0000 0.0000 000 @C"This comment will only appear at this rotation"
001 200.000 0.0000 0.0000 0.0000 0.0000 000
001 600.000 0.0000 0.0000 0.0000 0.0000 000
> @C"Below an example of the new MOVING_PLATE_ROTATION_SEQUENCE (MPRS)"
> @C"The comment applies to the MPRS below"
# @C"This comment flags a warning and is ignored"
> @MPRS:pid"002"
> @MPRS:code"PHS"
> @MPRS:name"Pacific Hotspots"
> @PP"PHS-PAC" @REF"Wessel.JGR.08" @DOI"10.1029/2007JB005499" @C"Model WK08-A" @GTS"GeeK07"
002 0.000 0.0000 0.000 0.000 901
002 0.780 49.3000 -49.500 -1.020 901
002 2.580 53.7200 -56.880 -2.660 901
002 5.890 59.6500 -66.050 -5.390 901
002 8.860 62.8700 -70.870 -8.230 901
002 12.290 65.3700 -68.680 -10.300 901
002 17.470 68.2500 -61.530 -15.500 901
# The foo pole by John
002 24.060 68.7800 -69.830 -20.400 901
002 28.280 67.7200 -70.800 -23.600 901
002 33.540 66.5700 -68.730 -27.700 901
002 40.100 65.4300 -64.250 -31.600 901
002 47.910 63.0200 -66.680 -34.600 901
002 53.350 60.6000 -69.670 -36.100 901
002 61.100 56.9300 -72.930 -38.400 901
002 74.500 50.0300 -78.350 -44.000 901
002 83.500 47.3000 -82.100 -48.800 901
002 95.000 46.9000 -82.680 -54.100 901
002 106.200 51.3200 -85.120 -60.100 901
002 112.300 52.1700 -85.800 -62.400 901
002 118.400 52.5300 -80.330 -66.500 901
002 125.000 54.1300 -88.180 -69.600 901
002 131.900 56.2200 -112.250 -78.600 901
002 144.000 54.4300 -123.570 -84.400 901
> @MPRS:pid"003" @MPRS:code"PPH" @MPRS:name"Present day Pacific hotspots"
> @PP"PPH-HOT"
003 0.000 0.0000 0.0000 0.0000 000
003 600.000 0.0000 0.0000 0.0000 000
> @MPRS:pid"101" @MPRS:code"NAM" @MPRS:name"North America"
> @PP"NAM-NWA" @REF"Mueller.99" @DOI"10.1016/S1874-5997(99)80036-7" @CHRONID"An5" @GTS"GEEK07"
101 0.000 0.0000 0.0000 0.000 714
101 10.900 81.0000 22.9000 2.840 714 @CHRONID"C5" @GTS"GEEK07"
101 20.100 80.6000 24.5000 5.530 714 @CHRONID"C6"
101 33.100 75.9900 5.9800 9.770 714 @CHRONID"C13"
101 40.100 74.5000 -1.2000 12.600 714 @CHRONID"C18"
101 47.900 74.9000 -4.6000 15.610 714 @CHRONID"C21"
101 55.900 80.6400 6.5700 17.900 714 @CHRONID"C25"
101 67.700 82.3000 -1.7000 21.510 714 @CHRONID"C30"
@CHRONID"C34"
101 83.500 76.8100 -20.5900 29.510 714
101 120.400 66.2800 -19.8200 54.440 714 @REF"Mueller.97" @DOI"10.1029/96JB01781"
101 126.700 66.1100 -18.9500 56.480 714 @REF"Mueller.97" @DOI"10.1029/96JB01781"
101 131.900 65.9500 -18.5000 57.450 714 @REF"Mueller.97" @DOI"10.1029/96JB01781"
101 139.600 66.1200 -18.3800 59.900 714 @REF"Mueller.97" @DOI"10.1029/96JB01781"
101 147.700 66.5400 -17.9800 62.080 714 @REF"Mueller.97" @DOI"10.1029/96JB01781"
101 154.300 67.1500 -15.9800 64.750 714 @REF"Mueller.97" @DOI"10.1029/96JB01781"
101 170.000 67.0900 -13.8600 70.550 714 @REF"Labails.EPSL.10" @DOI"10.1016/j.epsl.2010.06.024" @C"BSMA"
101 190.000 64.3100 -15.1900 77.090 714 @REF"Labails.EPSL.10" @DOI"10.1016/j.epsl.2010.06.024" @C"min closure"
101 203.000 64.2800 -14.7400 78.050 714 @REF"Labails.EPSL.10" @DOI"10.1016/j.epsl.2010.06.024" @C"min closure"
101 215.000 67.0000 -12.0000 79.000 714 @REF"Torsvik.Tectp.02" @DOI"10.1016/S1874-5997(99)80036-7" @C"Torsvik et al 2002"
101 320.000 67.0000 -12.0000 79.000 714 @REF"Torsvik.Tectp.02" @DOI"10.1016/S1874-5997(99)80036-7" @C"Torsvik et al 2002"
101 600.000 67.0000 -12.0000 79.000 714 @REF"Torsvik.Tectp.02" @DOI"10.1016/S1874-5997(99)80036-7" @C"Torsvik et al 2002"
> @MPRS:pid"102" @MPRS:code"GRN" @MPRS:name"Greenland"
> @PP"GRN-NAM" @C""this
is
a
very
long
comment
****
102 0.000 0.0000 0.0000 0.0000 101
102 33.100 0.0000 0.0000 0.0000 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C13 Derived"
102 40.100 62.4600 -28.0200 -1.2500 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C13 Derived"
102 43.800 63.2500 -79.5800 -1.8100 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C20 Derived"
102 47.900 60.6600 -97.2600 -2.8100 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C21 Derived"
102 49.700 61.5800 -97.0900 -3.3300 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C21 Derived"
102 53.300 39.6800 -116.1600 -3.7400 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C24 Derived"
102 55.900 19.2000 -136.1900 -3.1600 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C25 Derived"
102 68.700 41.1900 -169.5800 -5.7100 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C25 Derived"
102 79.100 61.3800 -157.7000 -8.4300 101 @REF"Gaina.EPSL.02" @DOI"10.1016/S0012-821X(02)00499-5" @CHRONID"C30 Derived"
102 83.500 65.3000 -122.4500 -11.0000 101 @REF"Roest.G.89" @DOI"10.1130/0091-7613(1989)017<1000:SFSITL>2.3.CO;2" @GTS"CK95G94" @CHRONID"C34"
102 92.000 66.6000 -119.4800 -12.2000 101 @REF"Roest.G.89" @DOI"10.1130/0091-7613(1989)017<1000:SFSITL>2.3.CO;2" @C"Start of seafloor spreading"
102 125.000 67.5000 -118.4800 -14.0000 101 @PP"GRN-NWA" @REF"Torsvik.RG.10" @DOI"10.1029/2007RG000227" @C"FITRECON"
102 600.000 67.5000 -118.4800 -14.0000 101 @PP"GRN-NWA" @REF"Torsvik.RG.10" @DOI"10.1029/2007RG000227"
> @MPRS:pid"103" @MPRS:code"NSL" @MPRS:name"North Slope Alaska"
103 0.000 0.0000 0.0000 0.0000 101 ! @PP"NSL-NAM"
103 126.000 0.0000 0.0000 0.0000 101 ! @PP"NSL-NAM"
103 132.000 60.0000 -126.0000 -3.0000 101 ! @PP"NSL-NAM" @REF"Alvey.EPSL.08" @DOI"10.1016/j.epsl.2008.07.036" @C"Derived"
103 136.500 60.0000 -126.0000 -6.5000 101 ! @PP"NSL-NAM" @REF"Alvey.EPSL.08" @DOI"10.1016/j.epsl.2008.07.036" @C"Derived"
103 139.600 60.0000 -126.0000 -10.0000 101 ! @PP"NSL-NAM" @REF"Alvey.EPSL.08" @DOI"10.1016/j.epsl.2008.07.036" @C"Derived"
103 142.500 65.0000 -130.2000 -30.0000 101 ! @PP"NSL-NAM" @AU"CG" @T"2008-06-xx" @C"FITRECON | Derived"

```

```

103 145.000 65.0000 -130.2000 -34.0000 101 ! @PP"NSL-NAM" @REF"Lawver.90"
103 600.000 65.0000 -130.2000 -34.0000 101 ! @PP"NSL-NAM" @REF"Lawver.90" @C"FITRECON"
> @MPRS:pid"201" @MPRS:code"SAM" @MPRS:name"South America"
> @PP"SAM-AFR" @REF"Mueller.99" @DOI"10.1016/S1874-5997(99)80036-7"
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201 20.1 58.5 -37.1 7.52 701 @CHRONID"C6"
201 33.1 56.17 -33.64 13.41 701 @CHRONID"C13"
#201 40.1 57.1 -32.5 16.6 701 @CHRONID"C18"
201 47.9 57.5 -31.2 19.7 701 @CHRONID"C21"
201 55.9 61.35 -32.21 22.27 701 @CHRONID"C25"
201 67.7 63.7 -33.5 25.39 701 @CHRONID"C30"
# Another example for comment data BEFORE the actual rotation line
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# @CHRONID"An34"
# @HELL:r"41.1911338" @HELL:Ns"75,16" @HELL:df"40." @HELL:kappahat"0.971082763"
# @HELL:matrix"((8.71113084E-07,-4.33230877E-07,-4.97091355E-07)(4.01436998E-07,3.23033819E-07,3.6493551E-07))"
201 83.500 61.8800 -34.2600 33.5100 701
#
# If you want you can put each comment for a following
# rotation on a single line.
# @PP"SAM-AFR"
# @REF"Torsvik.GJI.09"
# @DOI"10.1111/j.1365-246X.2009.04137.x"
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201 126.700 50.4000 -33.5000 54.4200 701 @PP"SAM-AFR" @REF"Nuernberg.Tectp.91" @DOI"10.1016/0040-1951(91)90231-G"
201 131.700 50.0000 -32.5000 55.0800 701 @PP"SAM-AFR" @REF"Nuernberg.Tectp.91" @DOI"10.1016/0040-1951(91)90231-G" @FITRECON
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203 126.700 0.0000 0.0000 0.0000 201 @PP"PAT-SAM" @C"adjusted timescale"
203 126.700 50.4000 -33.5000 54.4200 701 @PP"PAT-AFR" @C"adjusted timescale"
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> @REF"Gaina.JGR.98" @DOI"10.1029/98JB00386"
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833 52.0 0.0000 0.0000 0.0000 801 @PP"LHR-AUS"
833 53.300 -14.1900 130.4100 -0.7200 801 @PP"LHR-AUS"
833 55.800 -15.9300 133.4700 -2.1100 801 @PP"LHR-AUS"
833 57.900 -16.9300 136.2300 -3.7900 801 @PP"LHR-AUS"
833 61.200 -4.6500 131.5100 -4.4300 801 @PP"LHR-AUS"
833 62.500 -4.7100 132.6800 -5.1700 801 @PP"LHR-AUS"
833 64.000 -0.1900 130.3700 -5.4600 801 @PP"LHR-AUS"
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  Booktitle = {{Geological History of the Polar Oceans: Arctic Versus Antarctic}},
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@article{Torsvik.GJI.09,
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  Title = {{Integrated crustal thickness mapping and plate reconstructions for the high Arctic}},
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@article{Torsvik.RG.08,
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