GMAP2015 for Windows 7-8

USER MANUAL AND EXERCISES

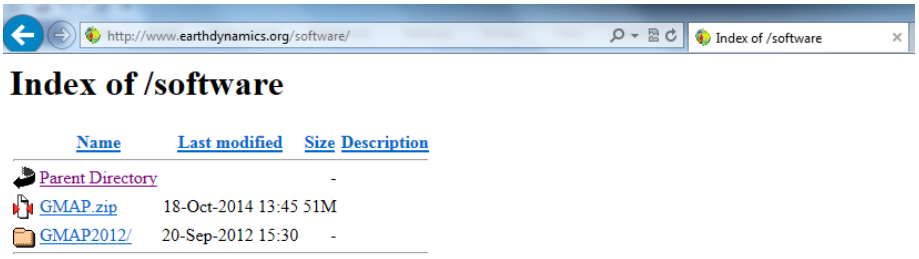
Trond Helge Torsvik

Center for Earth Evolutions and Dynamics (CEED)

University of Oslo (Norway)

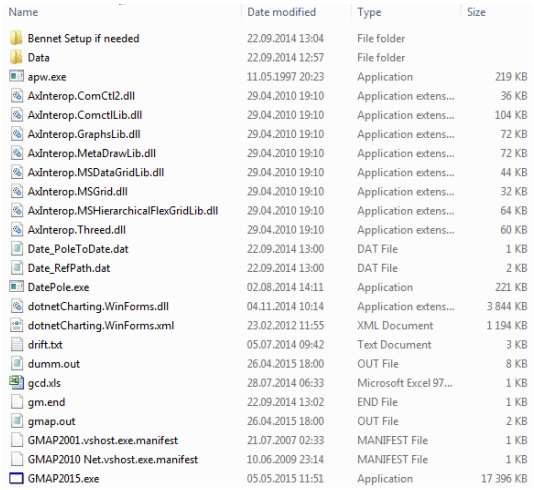
Download gmap.zip from:

http://www.earthdynamics.org/software/

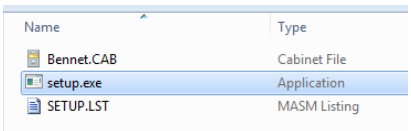


Software Installation:

(1) Unzip **gmap.zip** to C-drive and GMAP must be in c:\gmap with two sub-directories as seen below:



(2) If Gmap (or IAPD) as not ever been installed on your computer go to the Bennet Seup if needed and run **setup.exe**



(3) Click on **GMAP2015.exe** to start the program (or create a shortcut and put on desktop)

1. INTRODUCTION

GMAP is a state of the art computer program which performs all processing and plotting tasks usually associated with the storage and presentation of palaeomagnetic pole positions, and generation of palaeogeographic reconstructions. GMAP is menu-driven and easy to use; the user is never far removed from the basic data from which palaeogeographic reconstructions are derived, and therefore has a sense of total control over the program's performance.

GMAP can generate reconstructions based on individual palaeomagnetic poles, averaged palaeomagnetic poles, and digitally derived smooth (APW) curves. Palaeogeographic reconstructions can be saved to disk files, and later viewed in chronological order as `animations'.

GMAP is supplied with a full range of continental outlines. It is also possible to import new continents via simple ASCII files or ARC GIS shape files.

The GMAP software system package was originally developed by Trond Torsvik at the University of Bergen in 1982 and later with contributions from Lauri Pesonen, Mark Smethurst (Torsvik & Smethurst 1989) and Pavel Doubrovine. Some GMAP routines are currently being ported to GPlates (www.gplates.org) and this GMAP version is similar to earlier versions but can run under Windows 7 and 8.

1.1 MAIN PROGRAMS AND FILE-TYPES

Main program

GMAP2014_Win7.exe	Palaeogeographic reconstruction program

Main Data file types

*.C97	Continent outlines
*.VGP	Files containing virtual geomagnetic poles (VGP)
*.A97	Animation files

1.2 ABBREVIATIONS

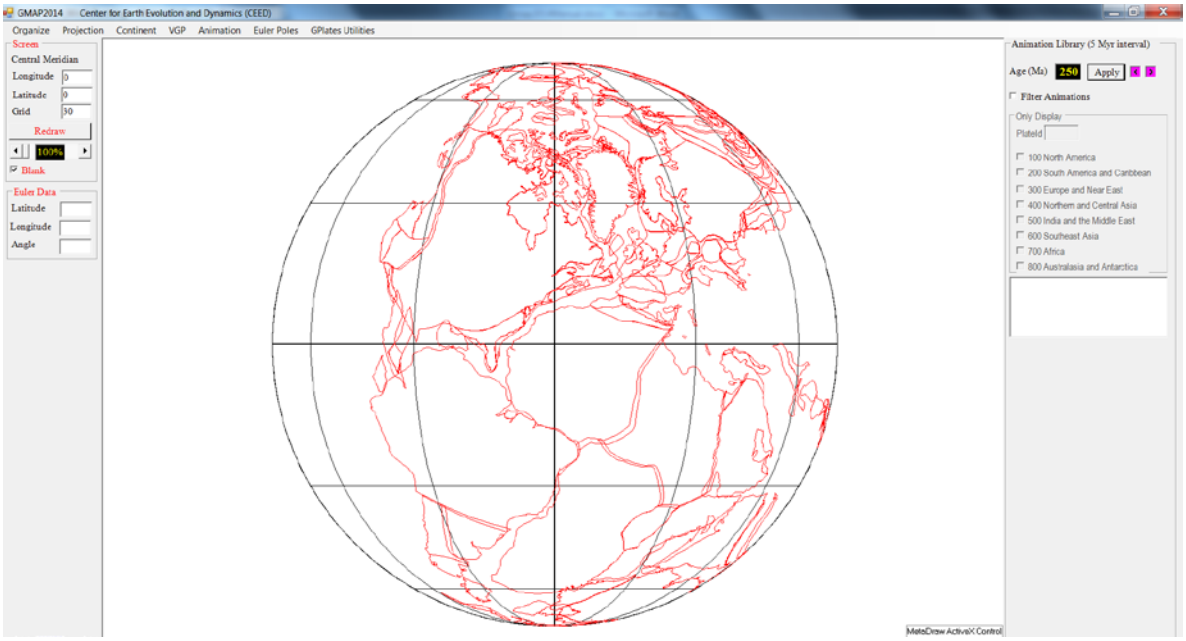
VGP	VIRTUAL GEOMAGNETIC POLE
APW	APPARENT POLAR WANDER
APWP	APW PATH
CONTINENT	A FILE CONTAINING LATITUDES AND LONGITUDES; THESE CAN W.G. BE COASTLINES OR TERRAIN BOUNDARIES
α_{95}	95 PERCENT CONFIDENCE CIRCLE ON MEAN REMANENCE
A95	95 PERCENT CONFIDENCE CIRCLE ON MEAN POLES
k	FISHER (1953) PRECISION PARAMETER
dp,dm	SEMI-AXES OF THE OVAL OF 95 PERCENT CONFIDENCE ABOUT THE VGP
DEC	MEAN REMANENCE DECLINATION
INC	MEAN REMANENCE INCLINATION
GLAT	LATITUDE OF SAMPLING SITE

GLON	LONGITUDE OF SAMPLING SITE
PLAT	VGP LATITUDE
PLON	VGP LONGITUDE

2. DESCRIPTION OF GMAP

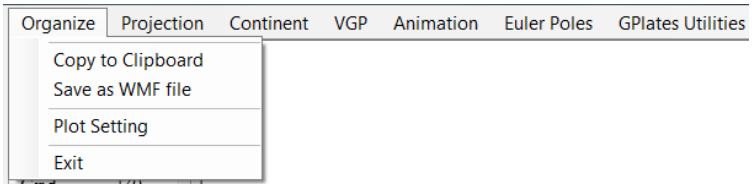
Select GMAP from the Program Manager Window option and double click the GMAP for Windows icon. After start-up the main menu is displayed (Fig. 1). An option in the top menu or the left-hand and right-hand panels (Fig. 2) may be selected through the use of the mouse and executed by clicking the mouse.

FIGURE 1 Main menu GMAP



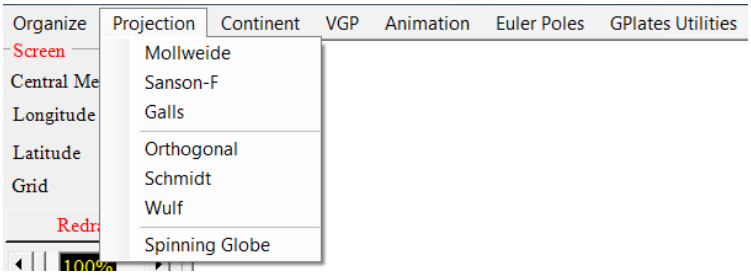
2.1 MAIN MENU OPTION (SUBOPTIONS)

Organize

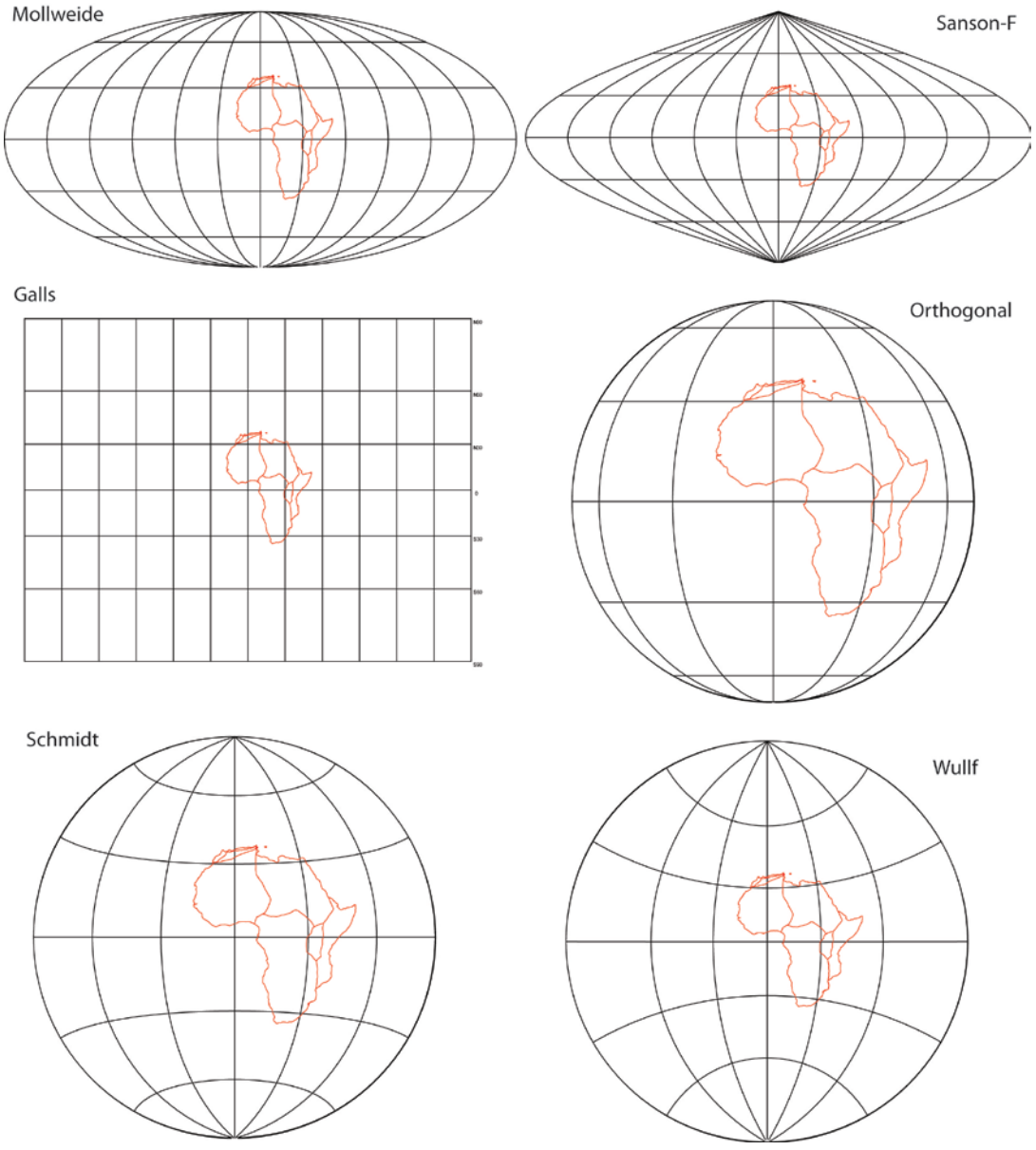


OPTION	EFFECT
Copy to Clipboard	Copy graphics to Clipboard and you can later 'Paste' the graphics into a drawing package in vector format.
Save as WMF file	Save graphics as a vector WFM file and you can later open file in a drawing package.
Plot Setting	ADJUST VGP SCREEN SETTINGS
Exit	END GMAP

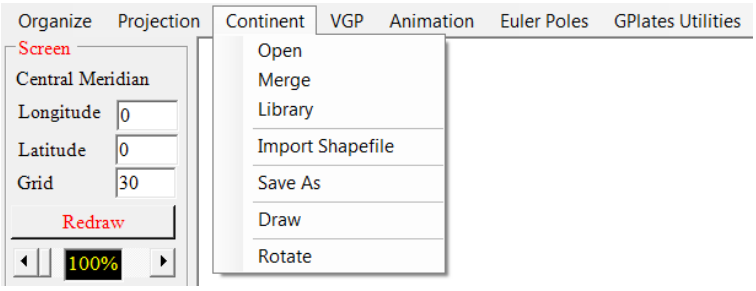
Projection



In GMAP you can select between 6 different projections. There is also a *Spinning Globe* (Orthogonal) option. The latter is rotated by holding down the left-hand mouse button. Only implemented for plotting CONTINENTS and VGPs (not Animation files) and can only plot one continental and VGP file at the time.

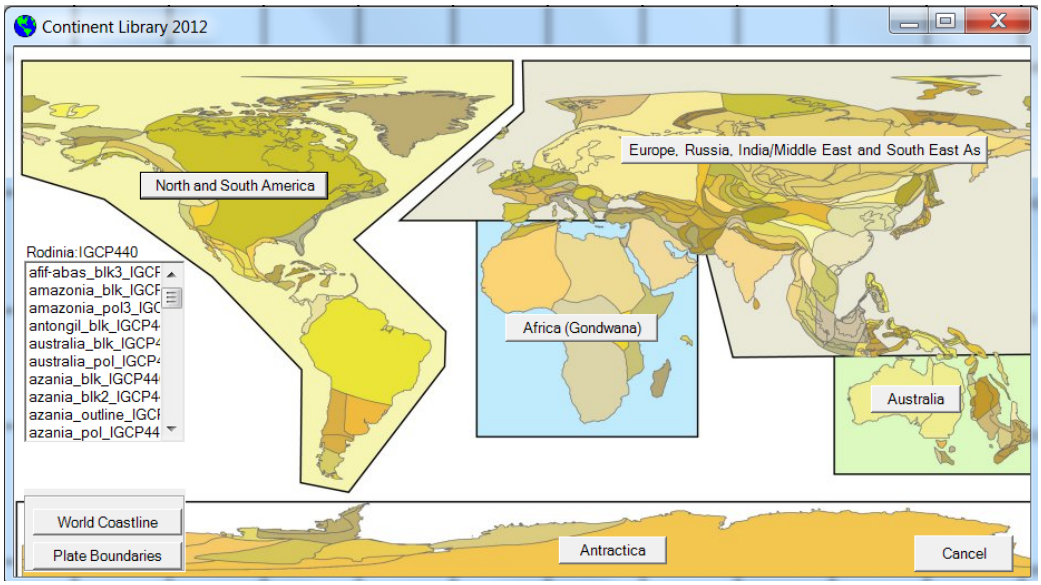


Continent

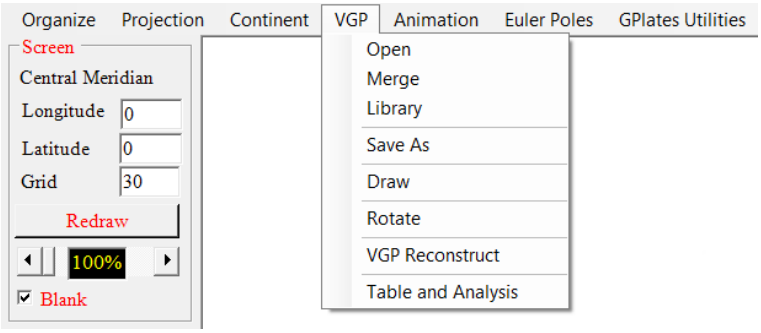


OPTION	EFFECT
Open	LOAD A CONTINENT FILE
Merge	MERGE CONTINENT FILES IN MEMORY
Library	DISPLAY CONTINENTAL LIBRARY FILES (see below)
Import Shapefile	IMPORT AND DRAW AN ARCG-GIS SHAPE FILE
Save As	SAVE A CONTINENT FILE
Draw	SCREEN DISPLAY OF CONTINENT
Rotate	ROTATE CONTINENT ACCORDING TO A PRE-DEFINED EULER-POLE

Continental files are located in *c:\gmap\data\continents* and they are typically named as *101_North American craton_1100.C97*. The leading number generally follows GPlates/Plates format followed by a named description. The final numbers indicate from when (in million years) the shape of the continent or terrane is valid. All continents can be selected interactively in the 'CONTINENT Library' option (see below). The library continents are those used in Torsvik et al. (2012).

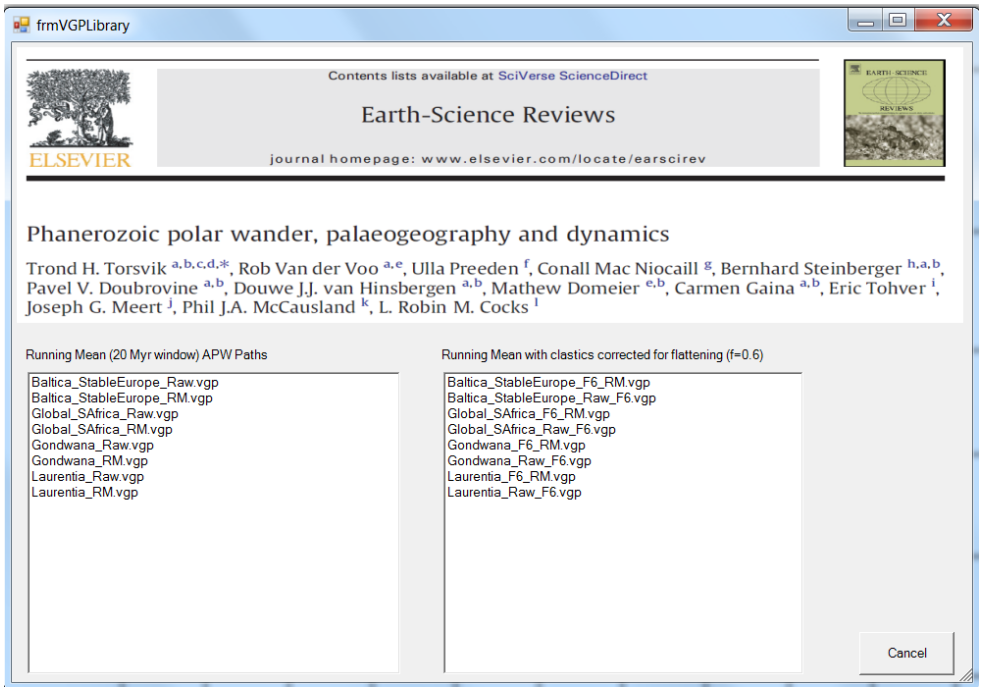


VGP

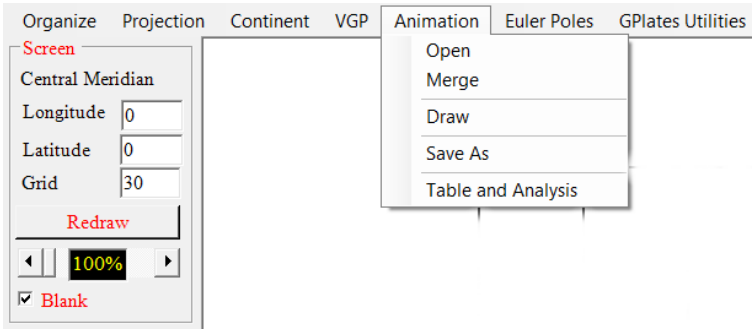


OPTION	EFFECT
Open	LOAD A VGP DATA FILE
Merge	MERGE VGP FILES
Library	SELECT VGP FILES FROM A PRECOMPILED LIBRARY (see below)
Save As	SAVE A VGP DATA FILE
Draw	SCREEN DISPLAY OF VGP DATA
Rotate	ROTATE VGP ACCORDING TO A REDEFINED EULER-POLE
VGP Reconstruct	MAKE A RECONSTRUCTION BASED ON A VGP
Table and Analysis	SHOW/EDIT/MANIPULATE VGP IN TABLE FORM

VGP files are located in *c:\gmap\data\VGPs* and the interactive "VGP Library" option seen below in located in *c:\gmap\data\VGPs\Library Paths ESR2012*. This library contain the files built in Torsvik et al. (2012) and you can select between files with raw pole data (-Raw) or running mean APW paths (_RM, 20 Myr window). The table to the right contains the same files as in the left-hand table but clastic sediments are corrected for potential inclination shallowing using a flattening factor (f) of 0.6. All corrected files are identified by _F6.

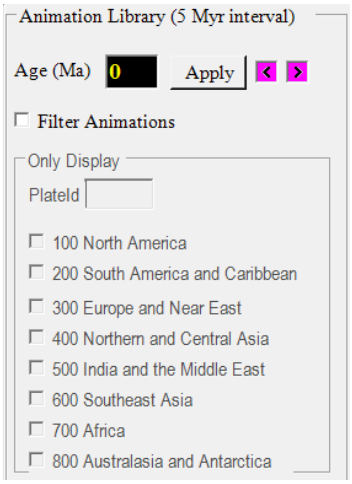


Animation

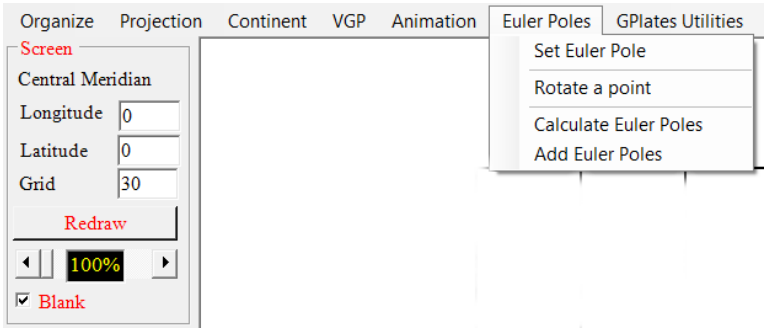


OPTION	EFFECT
Open	LOAD AN ANIMATION FILE
Merge	MERGE ANIMATION FILES
Draw	SCREEN DISPLAY OF ANIMATION FILE
Save As	SAVE AN ANIMATION FILE TO DISK
Table and Analysis	SHOW/EDIT ANIMATION FILE IN TABLE FORM

GMAP also includes an animation library that is controlled with the “Animation Library” controller that is located at the right-hand side of the startup form (see below). Pre-made reconstructions (animations) are those of Torsvik et al (2012) and they are in a palaeomagnetic frame without any true polar wander (TPW) corrections. Animations have been prepared in 5 Myr intervals back to 540 Ma. Type a reconstruction age and click ‘Apply’ or use arrows to go back and forth in time. To avoid doing the entire world you can activate ‘Filter Animations’ and select the areas you want to be reconstructed.

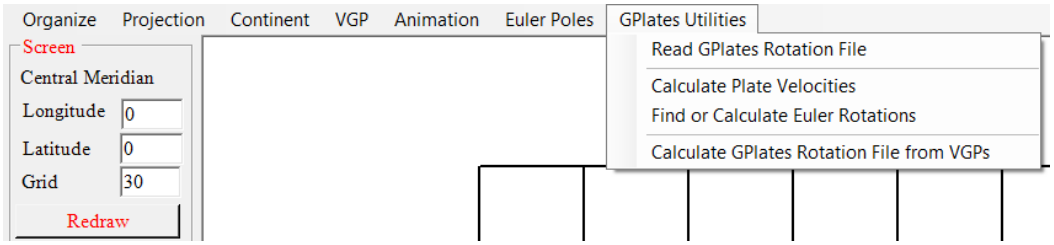


Euler



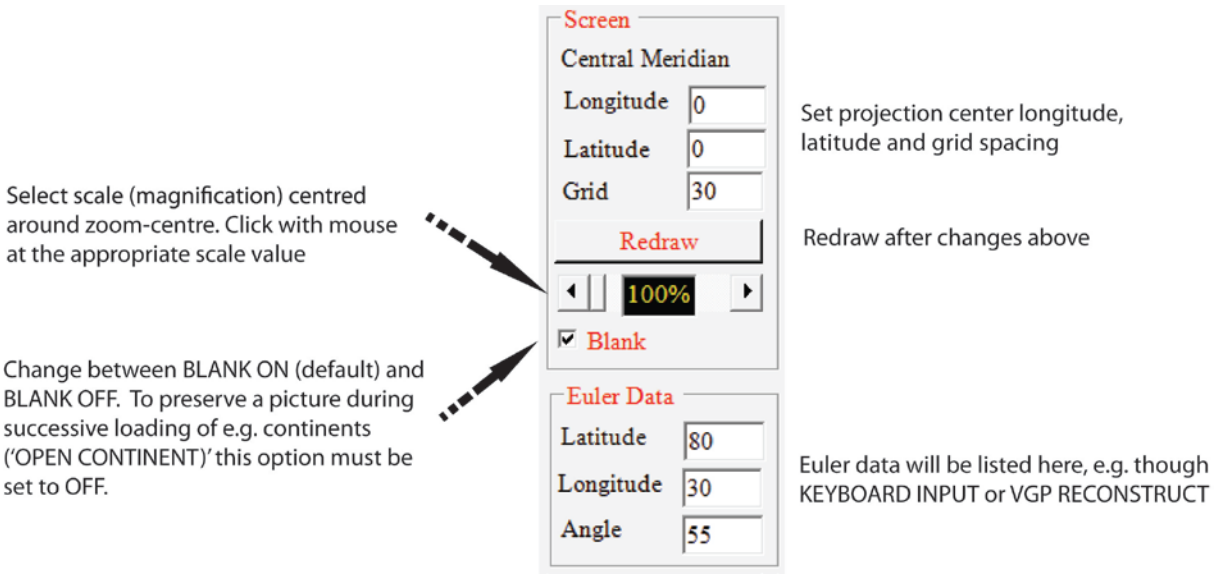
OPTION	EFFECT
Set Euler Pole	DEFINE A EULER POLE AND ROTATION ANGLE
Rotate a point	PERFORM AN EULER ROTATION
Calculate Euler Poles	CALCULATE AN EULER POLE
Add Euler Poles	CALCULATE AN EULER POLE BASED ON TWO SEPARATE EULER POLES

GPlates Utilities



OPTION	EFFECT
Read GPlates Rotation File	Read a standard GPlates formatted rotation file (original format)
Calculate Plate Velocities	Calculate plate velocities from GPlates Rotation File
Find or Calculate Euler Rotations	Find raw data in GPlates file or calculate abslute rotation parameters
Calculate GPlates Rotation File from VGPs	From VGP file create the Euler data needed in GPlates

3.0 LEFT-HAND PANEL



PANEL OPTION	EFFECT
Central Meridian	SET LATITUDE AND LONGITUDE FOR PROJECTION CENTER, AND GRID SPACING
Redraw	CLOCK AFTER CHANGING CENRAL MERIDIAN OR GRD SPACING
Blank	CHANGE BETWEEN BLANK ON AND BLANK OFF. BLANK ON IS DEFAULT, AND TO PRESERVE A PICTURE DURING SUCCESSIVE LOADING OF CONTINENTS ('OPEN CONTINENT)' THIS OPTION MUST BE SET TO OFF. CLICK WITH MOUSE FOR THE APPROPRIATE STATE
Scale	SELECT SCALE (MAGNIFICATION) CENTRED AROUND ZOOM-CENTRE CLICK WITH MOUSE AT THE APPROPRIATE SCALE VALUE (50-2000%)

4.0 Continent/VGP/Animation

4.1 OPEN (CONTINENT, VGP or ANIMATION files)

A list of CONTINENT (file extension .C97), VGP (file extension .VGP) or ANIMATION (file extension .A97) are displayed. Select the appropriate directory, drive and file name followed by <OK>. A range of CONTINENT/VGP/ANIMATION files can be found in c:\gmap\data\continents, c:\gmap\data\VGPs and c:\gmap\data\ANIMATIONS. The CONTINENTS are also found in the ANIMATION directory but all files in this directory are 'Read Only' to avoid overwriting original system files. CONTINENTS starting with a 3-digit number mainly follows GPlates (Plates) conventions

4.2 MERGE (CONTINENT, VGP or ANIMATION)

This option is identical to that described above, but the selected file will be merged with an existing CONTINENT/VGP/ANIMATION file in memory. These combined data can later be saved to a disk-file using option `SAVE AS' (CONTINENT/VGP or ANIMATION). Note, however, that the maximum permitted number of co-ordinates in a single continent outline is 30000 and 2000 data-points in a VGP file.

4.3 SAVE AS (CONTINENT, VGP or ANIMATION)

The purpose of this routine is to save modified CONTINENT, VGP or ANIMATION data to disk files. Merged CONTINENT files, EDITED CONTINENTS or rotated CONTINENT data can be saved under a new file name. The latter is useful for constructing ancient terranes or storing palaeogeographic maps. In option `DRAW CONTINENT' one can also add points/lines to the existing CONTINENT file which can later be saved under this option.

4.4 ROTATE (CONTINENT or VGP)

Define euler-data before selecting this option, either manually using the `KEYBOARD INPUT' option in the Euler-menu or from a file using the `OPEN' option. When rotating VGP's one can also rotate the sampling site latitude and longitude, to permit the generation of proper error ovals on data in their rotated positions.

Note that the CONTINENT outline/VGP's in memory are changed during rotation. To later perform a rotation on the original data-set the original continent file must first be re-loaded. Compound rotations can be performed using `KEYBOARD INPUT' and `ROTATE CONTINENT/VGP' repeatedly.

Example of compound rotation:

Problem: You wish to rotate the North American craton to its Devonian palaeoposition according to palaeomagnetic data from BALTICA.

(1) Select option `OPEN CONTINENT'

(2) Open North America craton (file = \data\continents\101_North American craton_1100.C97)

(If you now use option `DRAW CONTINENT', a map like Fig. 3A will appear on the screen)

(3) Use option `KEYBOARD INPUT' in the 'Euler Rotations' menu to register the rotation pole and angle which corrects for the Mesozoic/Cenozoic opening of the North Atlantic (e.g. use a classic Bullard et al. (1965) fit: c. 87 (latitude), 27 (longitude) and 37 (Euler-angle).

(4) Select option `ROTATE CONTINENT'. The continent outline will then be adjusted for the opening of the North Atlantic (If you then use option `DRAW CONTINENT', a map like Fig. 3B appears on the screen).

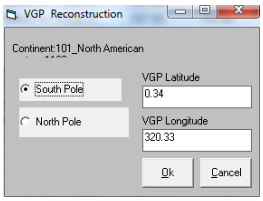
(5) Select option `OPEN VGP'.

(6) Open the fitted APW path for BALTICA/Europe (e.g. file data\VGPs\Baltica_Europe_2012.vgp supplied with the GMAP package).

(7) Select option `TABLE VGP' in the VGP menu.

(8) Select reference pole (e.g. pole 41 corresponding to an age of 400 Ma) by clicking the appropriate line at the line-number column.

(9) Select sub-option `RECONSTRUCT'.



Select south-pole and click the <OK> option.

Result

Continent data, already corrected for the opening of the North Atlantic is rotated by an amount which brings the selected reference VGP to the Southpole. Note that the Euler Rotation Pole required to do this will become the current Euler Pole setting which is displayed below the main menu, and can be used by option `ROTATE CONTINENT' to position other continents in a Devonian reconstructed position. North American craton will be displayed on the screen in a Devonian (400 Ma) configuration in 'European' co-ordinates.

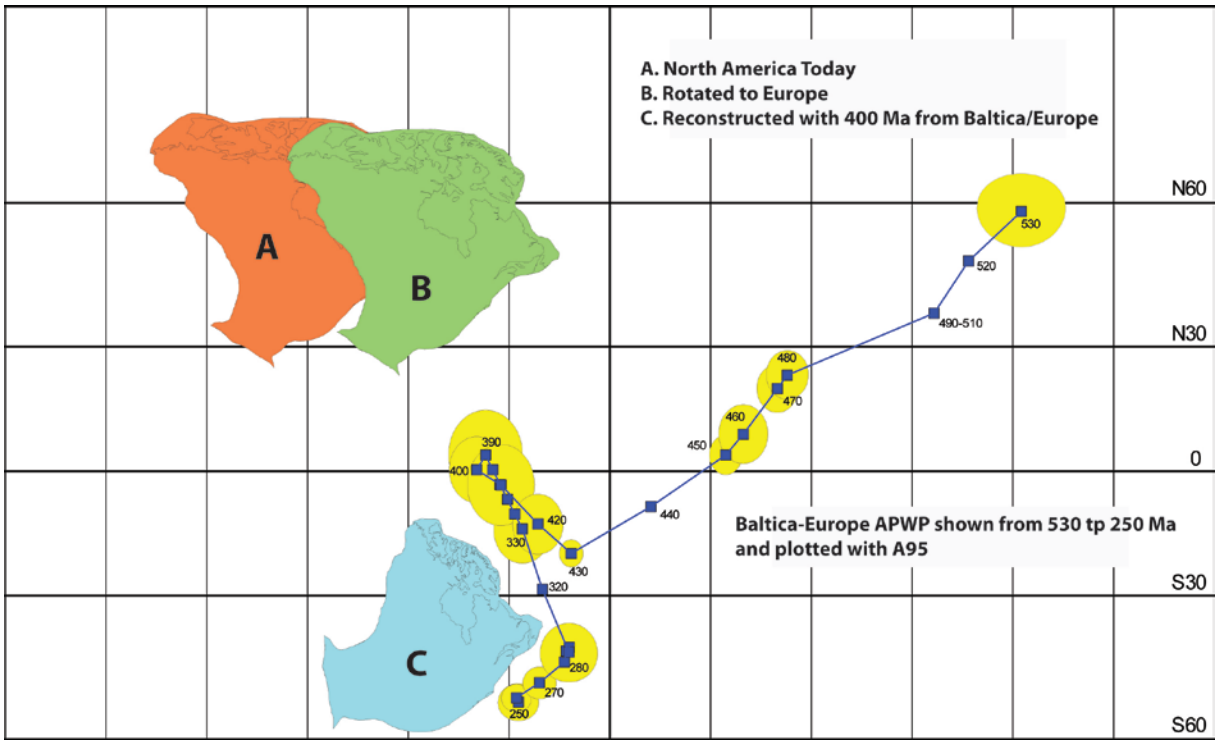


FIGURE 3 Example of compound rotation. (A) North-American craton displayed in present position. (B) Rotated into a Bullard et al. fit (lat=87, long=27, angle=37) with Europe, taking account of the opening of the North Atlantic.(C) The 'corrected' NAM positioned according to pole 41 in VGP file \data\VGPs\Baltica_Europe_2012.

4.5 VGP RECONSTRUCT

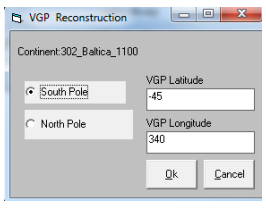
This option performs a reconstruction based on a VGP inputted from the keyboard. Enter VGP latitude and longitude and state whether it is a SOUTH (s) or NORTH (n) pole.

Example of how to produce a display for a map of the Permian palaeo-position for Baltica:

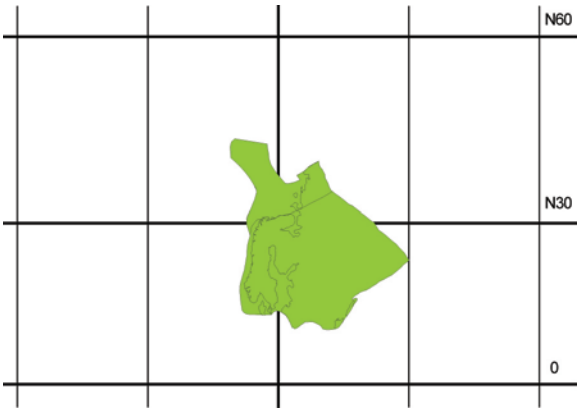
1. Load BALTICA (file = \data\continents\302_Baltica_1100.C97) using `OPEN CONTINENT'

2. Select option `VGP RECONSTRUCT' and enter -45 (VGP latitude) and 340 (VGP Longitude)

3. Select South-pole and click on <OK>.



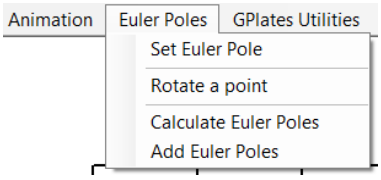
4. BALTICA will be displayed in `DRAW CONTINENT' in its PERMIAN position (see below).



4.6 DRAW CONTINENT (or VGP & ANIMATION)

In this option a CONTINENT, VGP or ANIMATION file is displayed on the screen using the pre-defined projection. The plot is centered on a `zoom-center', which by default is 0,0 (LAT,LONG). Blanking is ON by default.

5.0 Euler Rotations

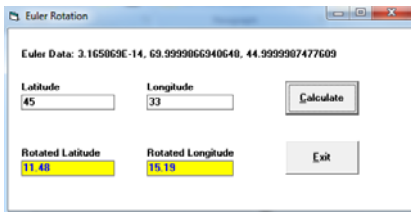


5.1 SET EULER POLE

This option enables the input of an Euler rotation pole from the keyboard which can subsequently be used by options `ROTATE CONTINENT (or VGP)' or `EULER ROTATION'.

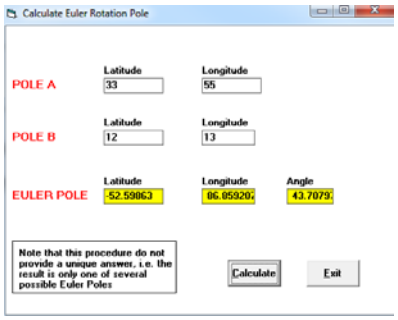
5.2 ROTATE A POINT

This utility routine performs Euler-rotations on VGP's entered interactively from the keyboard. The currently registered Euler Pole is used.



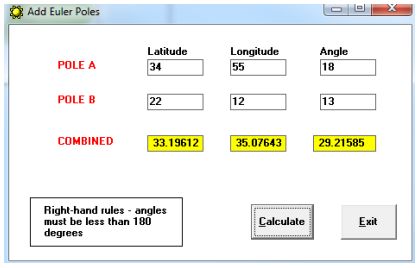
5.3 CALCULATE EULER POLES

This option enables calculation of an Euler rotation pole based on manual input of two geographic point (co-ordinates) or poles. Enter Latitude (LAT) and Longitude (LONG) for pole A and B, and the resultant rotation pole (Latitude & Longitude) and amount of rotation (Angle) will be displayed.



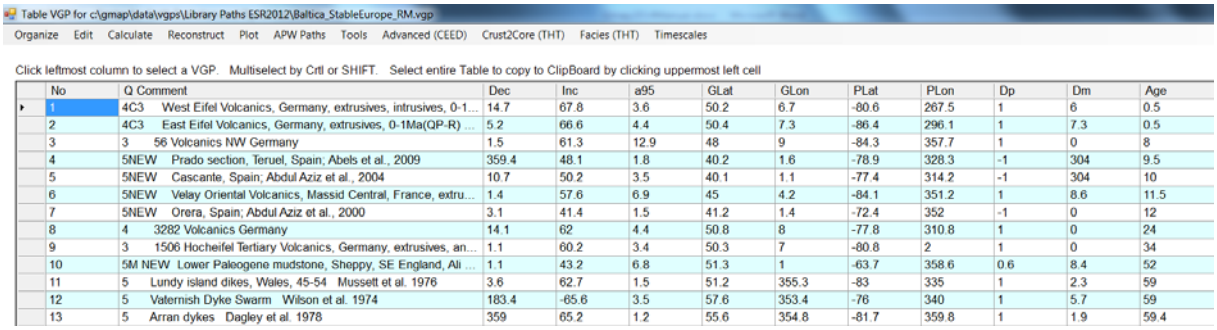
5.4 ADD EULER POLES

This option add/concatenates two Euler poles into a single resultant Euler pole. Enter latitude, longitude and angle for the two Euler poles and click on <Calculate>.



6. TABLE VGP

This is one of the most frequently used options in GMAP. Upon selecting this option the following table is displayed:

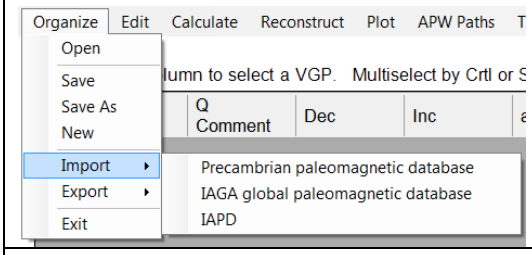
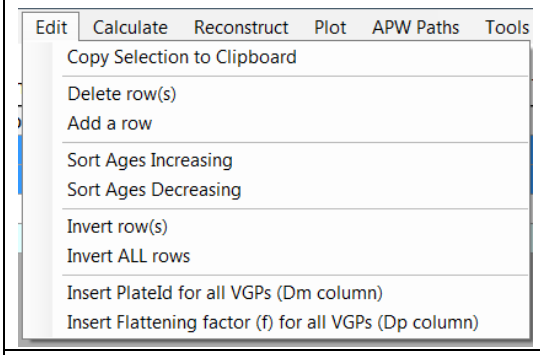


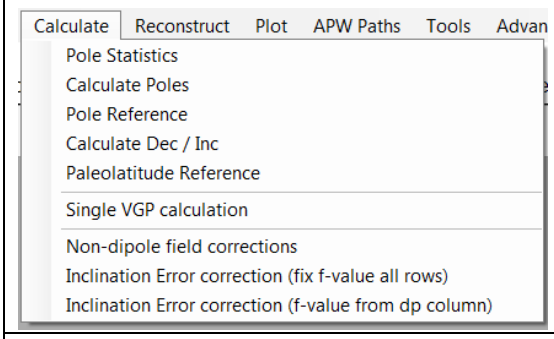
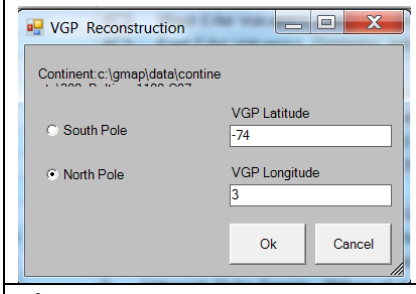
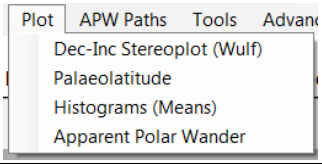
No	Q	Comment	Dec	Inc	a95	GLat	GLon	PLat	PLon	Dp	Dm	Age
1	4	C3 West Eifel Volcanics, Germany, extrusives, intrusives, 0-1...	14.7	67.8	3.6	50.2	6.7	-80.6	267.5	1	6	0.5
2	4	C3 East Eifel Volcanics, Germany, extrusives, 0-1Ma(QP-R) ...	5.2	66.6	4.4	50.4	7.3	-86.4	296.1	1	7.3	0.5
3	3	56 Volcanics NW Germany	1.5	61.3	12.9	48	9	-84.3	357.7	1	0	8
4	5	NEW Prado section, Teruel, Spain; Abels et al., 2009	359.4	48.1	1.8	40.2	1.6	-78.9	328.3	-1	304	9.5
5	5	NEW Cascante, Spain; Abdul Aziz et al., 2004	10.7	50.2	3.5	40.1	1.1	-77.4	314.2	-1	304	10
6	5	NEW Velay Oriental Volcanics, Massid Central, France, extru...	1.4	57.6	6.9	45	4.2	-84.1	351.2	1	8.6	11.5
7	5	NEW Orera, Spain; Abdul Aziz et al., 2000	3.1	41.4	1.5	41.2	1.4	-72.4	352	-1	0	12
8	4	3282 Volcanics Germany	14.1	62	4.4	50.8	8	-77.8	310.8	1	0	24
9	3	1506 Hocheifel Tertiary Volcanics, Germany, extrusives, an...	1.1	60.2	3.4	50.3	7	-80.8	2	1	0	34
10	5	M NEW Lower Paleogene mudstone, Sheppy, SE England, Ali ...	1.1	43.2	6.8	51.3	1	-63.7	358.6	0.6	8.4	52
11	5	Lundy island dikes, Wales, 45-54 Mussett et al. 1976	3.6	62.7	1.5	51.2	355.3	-83	335	1	2.3	59
12	5	Vaternish Dyke Swarm Wilson et al. 1974	183.4	-65.6	3.5	57.6	353.4	-76	340	1	5.7	59
13	5	Arran dykes Dagley et al. 1978	359	65.2	1.2	55.6	354.8	-81.7	359.8	1	1.9	59.4

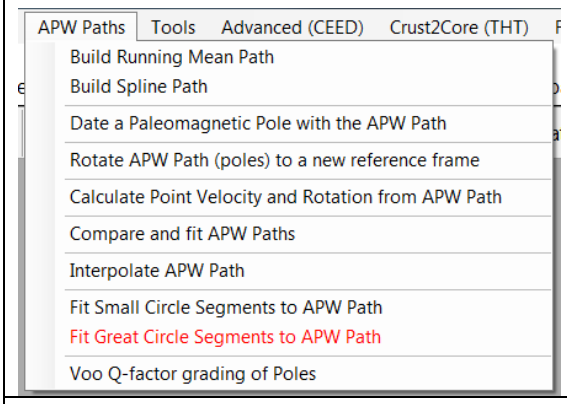
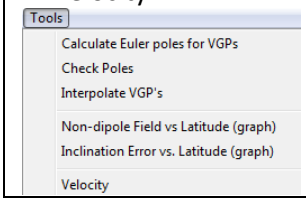
Column#	
1- Nr.	Pole number
2Q Comment	Combined character string of Van der Voo classification/grading (1-7) and and pole information. This string is important and controls weighting in the fitting of smooth APW paths. For example a pole with `Q' factor = 7 are entered as `7'
3- DEC	Remanence Declination
4- INC	Remanence Inclination
5- a95	95 % confidence circle on mean remanence direction
6- GLAT	Latitude of sampling site
7- GLON	Longitude of sampling site
8- PLAT	Latitude of VGP
9- PLON	Longitude of VGP
10- dp	Half-angle of the confidence on the VGP in the direction of the palaeo-meridian. This column is also used to store other parameters
11- dm	Half-angle of the confidence on the VGP perpendicular to the palaeo-meridian This column is also used to store other parameters
12- AGE	VGP age. All poles must be assigned an age if a smooth path is to be fitted to them. During hard-copying of VGP data the age will be printed next to the pole.

Note that VGP files imported from the Global Palaeomagnetic Database ('Organize', 'Import') substitute column #2 with DEMAGCODE and other information. Column #12 (AGE) is a mean of Low and high magnetic age stated in the database.

6.1 MAIN MENU AND SUBOPTIONS

OPTION/SUBOPTION	EFFECT
Organize Open Save Save As New Import Exit 	 Open a VGP file Save VGP File Save VGP with a new name Create a new VGP file. Import VGPs from: • Precambrian paleomagnetic database • IAGA global paleomagnetic database • IAPD Return to main menu
Edit Copy Selection to Clipboard Delete row(s) Add a row Sort Ages Increasing Sort Ages Decreasing Invert row(s) Invert all rows Insert PlateId for all VGP's (Dm column) Insert Flattening factor (f) for all VGPs (Dp column) 	 Copy rows to clipboard and e.g. paste into e.g. Excel. Select entire Table to copy to Clipboard by clicking uppermost left cell Delete one or several entries in the Table. Select pole by clicking on numerical row code at the first column. Multi-select by Crtl or SHIFT Add a pole to the Table Sort ages Sort ages Invert VGP polarity of one or several poles. Invert VGP polarity of all poles Fills the Dm column with continental plate id's as in GPLates Fills the Dp column with flattening factor (f). Typical used for clastic sediment poles and you can later recalculate the pole based on the given f-factor.
Calculate Pole Statistics Calculate poles	 Calculate mean of the listed VGP's (A95) Determine the palaeomagnetic pole-position for all data in the Table. Declination, inclination and sampling position present in data-set.

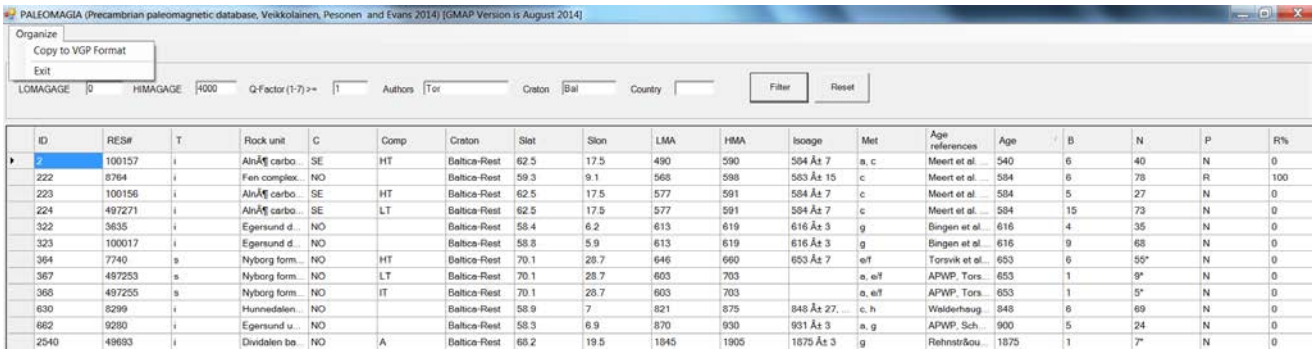
Pole Reference Calculate Dec / Inc Paleolatitude Reference Single VGP Calculation Non-dipole field correction Inclination Error Correction (fix f-value al rows) Inclination Error Correction (f-value from dp column) 	Calculate amount of rotation and flattening. Enter Reference Pole and A95 Calculate declination and inclination Based on VGP latitude & longitude and sampling position Enter latitude & longitude (optional) for which palaeolatitudes are to be determined. Note that latitude & longitude will replace original sampling co/ordinates in the VGP Table. This enables the operator to calculate 'local' declination and inclinations at the selected reference locality. Calculate a pole based on declination, inclination and sampling location Type G1 and G2 (octupole) contribution and a new inclination and pole will be calculated for the entire table Type f (flattening factor) and inclination and pole will be recalculated Inclination and pole recalculated from f-value in dp column
Reconstruct 	Perform a reconstruction based on a VGP in the table Note - Load a continent prior to this operation • Select reconstruction pole by clicking on numerical row code at the first column • Select North or South pole • Resulting reconstruction will be displayed in mode 'DRAW CONTINENT'
Plot Dec-Inc Stereoplot (Wulf) Palaeolatitude Histograms (Means) Apparent Polar Wander 	Display declination and inclinations in a Wulf plot Calculate and display latitudes based on inclination Display data in histograms (use any column in Table) Calculate APW (from running mean or spline path) and display in X-Y plot

APW Paths Build Running Mean Path Build a Spline Path Voo Grading (Q) Timescale *(not updated)* 	Fit a smooth APW path to the data in the Table using running means Fit a smooth APW path to the data in the Table using splines
Tools Calculate Euler poles for VGPs Check poles Interpolate VGPs Non-dipole Field vs. Latitude Inclination Error vs. Latitude Velocity 	Calculate Euler poles for entire Table. Select North or South pole. Cross-checking type pole and calculated from dec, inc and location Interpolating by typing interval Draw a graph based on G1 and G2 Draw a graph based on f (flattening factor) Engage calculation of velocties from VGPs *(very old routine)*

Note: All alterations to data in the Table will only affect the dataset in memory, and not on the disk. To save alterations made in 'TABLE VGP' to disk, use option 'SAVE AS (VGP)' in the main menu.

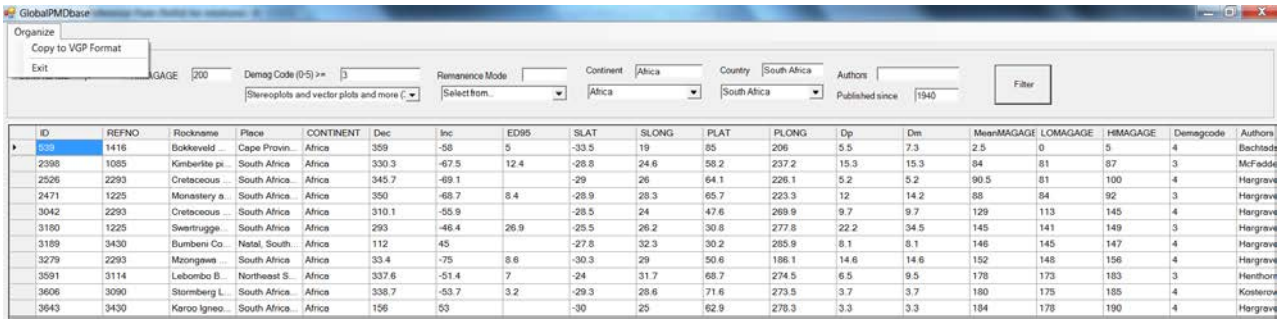
6.2 IMPORT

6.2.1. Precambrian paleomagnetic database



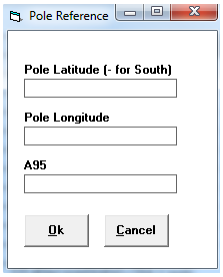
ID	RES#	T	Rock unit	C	Comp	Craton	Slat	Slon	LMA	HMA	Isoage	Met	Age references	Age	B	N	P	R%
2	100157	i	AlnÃ¶ carbo...	SE	HT	Baltica-Rest	62.5	17.5	490	590	584 Â± 7	a, c	Meert et al. ...	540	6	40	N	0
222	8764	i	Fen complex...	NO		Baltica-Rest	59.3	9.1	568	598	583 Â± 15	c	Meert et al. ...	584	6	78	R	100
223	100156	i	AlnÃ¶ carbo...	SE	HT	Baltica-Rest	62.5	17.5	577	591	584 Â± 7	c	Meert et al. ...	584	5	27	N	0
224	497271	i	AlnÃ¶ carbo...	SE	LT	Baltica-Rest	62.5	17.5	577	591	584 Â± 7	c	Meert et al. ...	584	15	73	N	0
322	3635	i	Egersund d...	NO		Baltica-Rest	58.4	6.2	613	619	616 Â± 3	g	Bingen et al...	616	4	35	N	0
323	100017	i	Egersund d...	NO		Baltica-Rest	58.8	5.9	613	619	616 Â± 3	g	Bingen et al...	616	9	68	N	0
364	7740	s	Nyborg form...	NO	HT	Baltica-Rest	70.1	28.7	646	660	653 Â± 7	e/f	Torsvik et al...	653	6	55*	N	0
367	497253	s	Nyborg form...	NO	LT	Baltica-Rest	70.1	28.7	603	703		a, e/f	APWP, Tors...	653	1	9*	N	0
368	497255	s	Nyborg form...	NO	IT	Baltica-Rest	70.1	28.7	603	703		a, e/f	APWP, Tors...	653	1	5*	N	0
630	8299	i	Hunnedalen...	NO		Baltica-Rest	58.9	7	821	875	848 Â± 27, ...	c, h	Walderhaug...	848	6	69	N	0
662	9280	i	Egersund u...	NO		Baltica-Rest	58.3	6.9	870	930	931 Â± 3	a, g	APWP, Sch...	900	5	24	N	0
2540	49693	i	Dividalen ba...	NO	A	Baltica-Rest	68.2	19.5	1845	1905	1875 Â± 3	g	Rehnstr&ou...	1875	1	7*	N	0

6.2.2. IAGA global paleomagnetic database



ID	REFNO	Rockname	Place	CONTINENT	Dec	Inc	ED95	SLAT	SLONG	PLAT	PLONG	Dp	Dm	MeanMAGAGE	LOMAGAGE	HIMAGAGE	Demagcode	Authors
539	1416	Bokkeveld ...	Cape Provin...	Africa	359	-58	5	-33.5	19	85	206	5.5	7.3	2.5	0	5	4	Bachtadse
2398	1085	Kimberlite pi...	South Africa	Africa	330.3	-67.5	12.4	-28.8	24.6	58.2	237.2	15.3	15.3	84	81	87	3	McFadde
2526	2293	Cretaceous ...	South Africa...	Africa	345.7	-69.1		-29	26	64.1	226.1	5.2	5.2	90.5	81	100	4	Hargrave
2471	1225	Monastery a...	South Africa...	Africa	350	-68.7	8.4	-28.9	28.3	65.7	223.3	12	14.2	88	84	92	3	Hargrave
3042	2293	Cretaceous ...	South Africa	Africa	310.1	-55.9		-28.5	24	47.6	269.9	9.7	9.7	129	113	145	4	Hargrave
3180	1225	Swartrugge...	South Africa	Africa	293	-46.4	26.9	-25.5	26.2	30.8	277.8	22.2	34.5	145	141	149	3	Hargrave
3189	3430	Bumbeni Co...	Natal, South...	Africa	112	45		-27.8	32.3	30.2	285.9	8.1	8.1	146	145	147	4	Hargrave
3279	2293	Mzongawa ...	South Africa	Africa	33.4	-75	8.6	-30.3	29	50.6	186.1	14.6	14.6	152	148	156	4	Hargrave
3591	3114	Lebombo B...	Northeast S...	Africa	337.6	-51.4	7	-24	31.7	68.7	274.5	6.5	9.5	178	173	183	3	Henthorn
3606	3090	Stormberg L...	South Africa...	Africa	338.7	-53.7	3.2	-29.3	28.6	71.6	273.5	3.7	3.7	180	175	185	4	Kosterov
3643	3430	Karoo Igneo...	South Africa...	Africa	156	53		-30	25	62.9	278.3	3.3	3.3	184	178	190	4	Hargrave

6.2 POLE REFERENCE

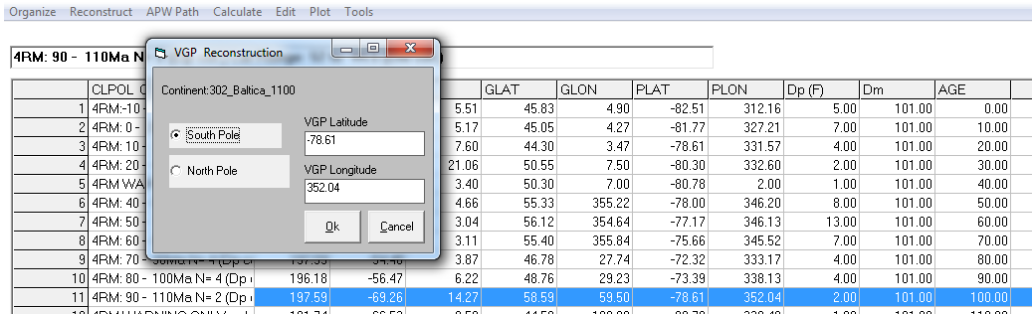


This option is useful when dealing with displaced and rotated terranes. A reference pole in the term of latitude, longitude and A95 is required

Based on this reference pole, the declination differences between the reference and tabulated data are calculated. This provides estimates of the potential rotation angle (about a vertical axis) of each pole in the table relative to the reference pole. Differences in inclination are also calculated, which provide estimates of palaeolatitudinal differences (or remanence flattening).

When using the `PRINT TABLE' option (above) after performing this calculation, a detailed listing of estimated rotation and flattening angles together with the associated errors will be printed. On the screen the data will be displayed from column 12 and onwards.

6.3 RECONSTRUCT



	CLPOL				GLAT	GLON	PLAT	PLON	Dp (F)	Dm	AGE
1	4RM:-10			5.51	45.83	4.90	-82.51	312.16	5.00	101.00	0.00
2	4RM: 0 -			5.17	45.05	4.27	-81.77	327.21	7.00	101.00	10.00
3	4RM: 10			7.60	44.30	3.47	-78.61	331.57	4.00	101.00	20.00
4	4RM: 20			21.06	50.55	7.50	-80.30	332.60	2.00	101.00	30.00
5	4RM WA			3.40	50.30	7.00	-80.78	2.00	1.00	101.00	40.00
6	4RM: 40			4.66	55.33	355.22	-78.00	346.20	8.00	101.00	50.00
7	4RM: 50			3.04	56.12	354.64	-77.17	346.13	13.00	101.00	60.00
8	4RM: 60			3.11	55.40	355.84	-75.66	345.52	7.00	101.00	70.00
9	4RM: 70			3.87	46.78	27.74	-72.32	333.17	4.00	101.00	80.00
10	4RM: 80 - 100Ma N= 4 (Dp	196.18	-56.47	6.22	48.76	29.23	-73.39	338.13	4.00	101.00	90.00
11	4RM: 90 - 110Ma N= 2 (Dp	197.59	-69.26	14.27	58.59	59.50	-78.61	352.04	2.00	101.00	100.00

This is the most heavily used routine in performing reconstruction's based on palaeomagnetic data. This function is also available in the main menu under the name `VGP RECONSTRUCT'.

In GMAP, the euler-pole and rotation angle which is required to rotate the selected VGP to the present geographic NORTH (n) or SOUTH (s) POLE is determined and becomes the current setting for the euler rotation listed under the main menu.

The user must note that any pole-position can result in two possible palaeo-positions for a continent, one opposite to the other, depending on the poles polarity. Therefore, attention should be paid at all times to the polarity of the VGP's in the table, so that proper account can be taken of it. Note that the function below, `APW PATH', requires that all the VGP's in the table have the same polarity.

In order to use this option, first load a VGP file and the contenent you wish to reconstruct. Click in the table on the line (pole) you wish to use for reconsruction.

6.4 APW PATH

To aid the definition of APW trends within tectonic units and to compare such trends between tectonic units GMAPW includes a method of fitting smooth path to a series of VGP's, of various ages,

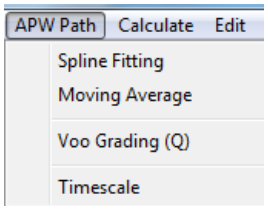
which has a location and time progression. Path fitting constitutes interpolation; reducing data sets to a simpler, and to some extent interpreted, form.

A number of numerical methods for fitting smooth paths to palaeomagnetic poles have been offered in the literature (Gould, 1969; Parker and Denham, 1979; Thompson and Clark, 1981, 1982; Clark and Thompson, 1984; Jupp and Kent, 1987). In GMAP we have used the method of Jupp and Kent (1987) because it is statistically rigorous, is independent of the co-ordinate system, and is most sympathetic to the concept of APW. The method aims to fit `spherical smoothed splines' to a given data-set, consisting of pole positions and error parameter.

It is possible to generate a number of paths with different levels of smoothing. This is done by adjusting a smoothing parameter used by the computer program. In GMAP the data can be individually weighted according to their alfa95, so that the route taken by the smooth path through the data set will depend on both the distribution of the data on the globe and the standard error for each of the palaeopole positions. The lower the reported angular error for a pole position, the closer the curve will pass by it. We have also implemented a weighting procedure based on the Van der Voo's (1988) reliability index `Q' (grades 1 to 7; least to most reliable).

It is clear that the angular error associated with a particular palaeomagnetic pole position is far from an adequate description of the quality or reliability of that pole. For example, uncertainty in the age of the result has a direct bearing on the angular uncertainty which should be associated with it, since apparent polar wander might be continuing within the time period of uncertainty. Instead of weighting pole positions solely on the basis of criterion (2) in Van der Voo's reliability scheme (alfa95), it is informative to weight the data in proportion to their 'Quality factors'. This causes the smooth path to pass close to the data which score `7', full-marks, and be only gently guided by those data with lower reliabilities.

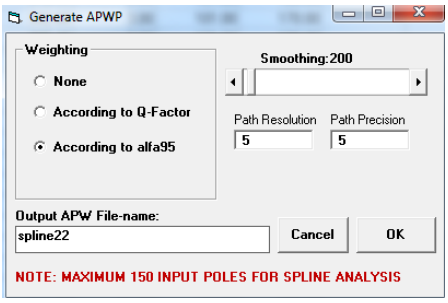
GENERATION OF APW PATHS



(1) Load a VGP file via the main-menu option `OPEN VGP' (e.g. file \data\VGPs\NorthAmerica2008_ROG.vgp).

(2) Select option `TABLE VGP'

(3) Select sub-option `SPLINE FITTING'



(4) Select (a) No weighting

(b) Weighting according to `Q' factor

(c) Weighting according to alfa95

If option `b' is selected, the `Q' factor for every VGP in the table must be encoded in the first character of the VGP `code' (see section 3.8). If a `Q' factor is not present included, `Q' will be set to zero reliability.

If option `c' is selected, the alfa95 must be included in the table of data.

(5) Input SMOOTHING PARAMETER (value 10 to 10000)

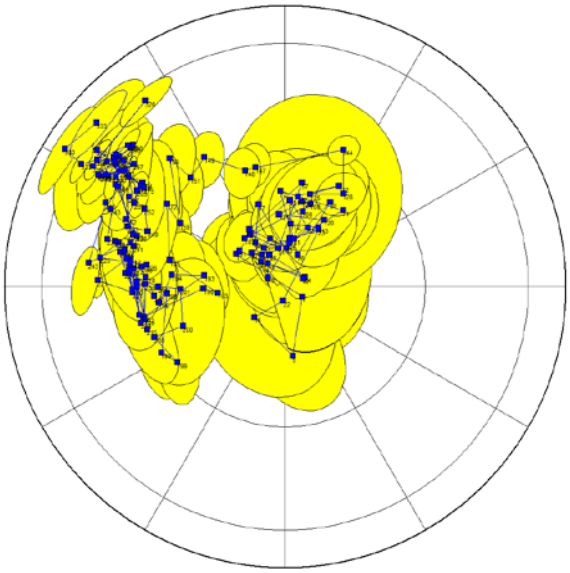
A high value results in extreme smoothing. Values in the order of 100 to 200 generally result in moderate smoothing (Fig. 11).

(6) Input VGP FILE-NAME for the output fitted path.

The fitted path, when generated, will be displayed on the graphic screen in option `DRAW VGP' (3.9) in the main menu.

Note:

The original VGP file is ‘shut down’ and replaced with the new APW file (spline file).



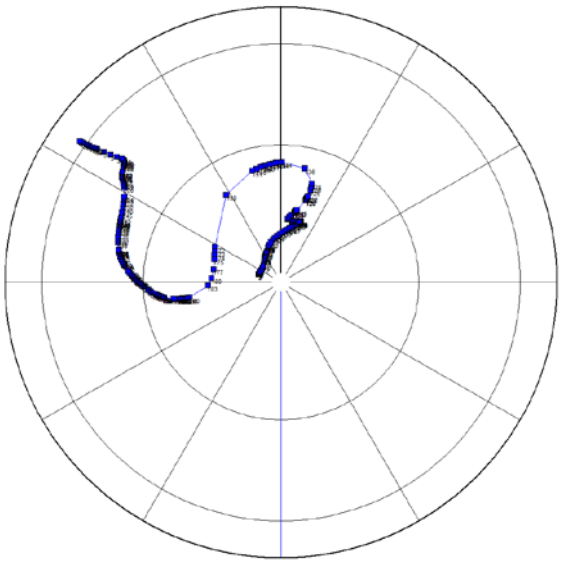
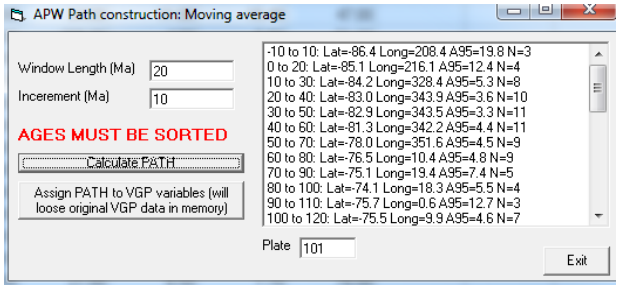


FIGURE 10 `SPLINE FITTING' option. Left: File \data\VGPs\NorthAmerica2008_ROG.vgp plotted with dp/dm ovals. Right: Spline fitting with smoothing parameter=200 and weighted by alfa95.



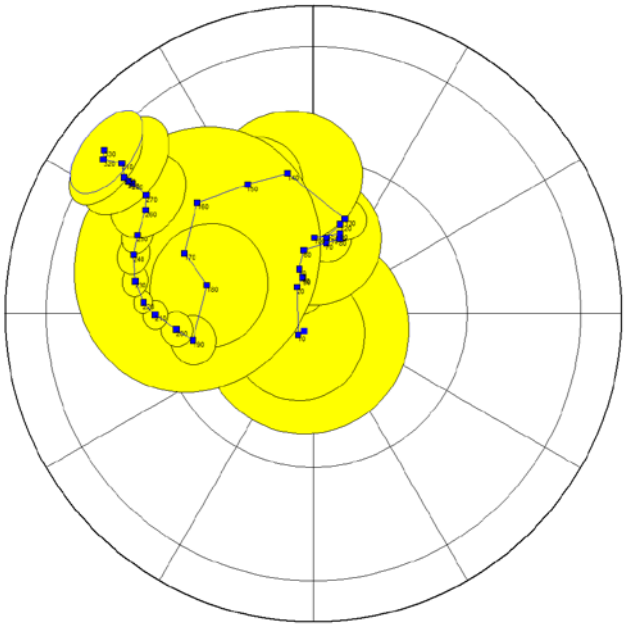
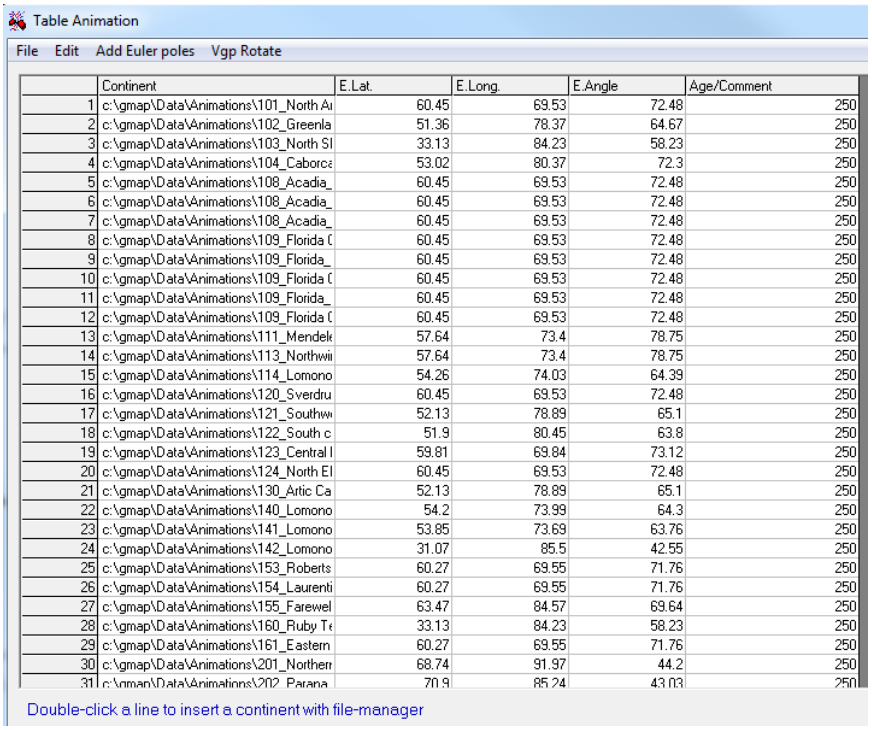
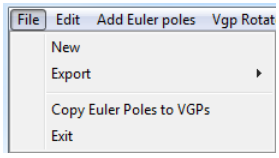


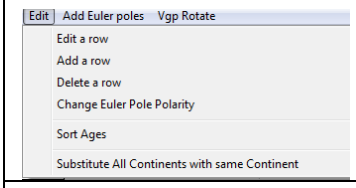
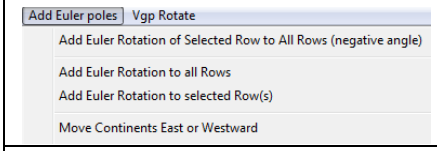
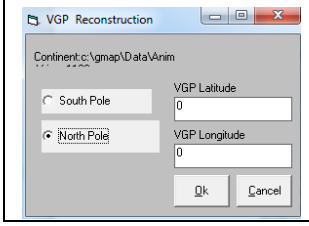
FIGURE 10 `MOVING AVERAGE' option on file \data\VGPs\NorthAmerica2008_ROG.vgp and plotted with A95 ovals.

7. TABLE ANIMATION



This option is used to edit (use option 'OPEN ANIMATION') or create animation files. The main menu consists of the following options:

OPTION (SUBOPTION)	EFFECT
File New Export To EXCEL To GMT (all reconstructed) To GPlates rotation format Copy Euler Poles to VGP Exit 	 Create a new file Copy Euler poles to memory and display with "DRAW VGP"
Edit Edit a row Add a row Delete a row Sort Ages	 Edit a single line. Select line by clicking on numerical row code at the first column Add a row to the Table Delete one or several lines. Select line(s) by clicking on numerical row code at the first column or drag the mouse to include several lines

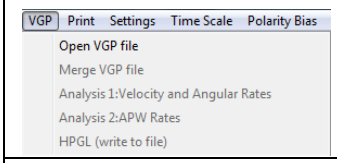
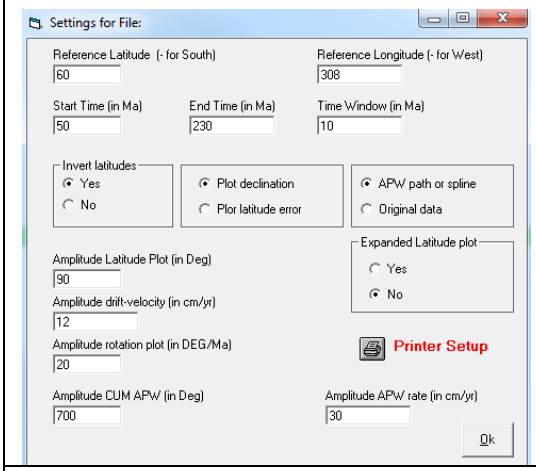
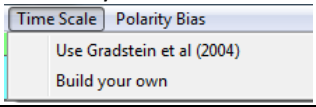
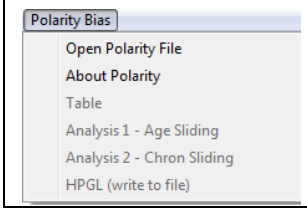
Subsitute All Continents with same continent  	
Add Euler Poles Add Euler Rotation of Selected Row to All Rows (negative angle) Add Euler Rotation to all Rows Add Euler Rotation to Selected Rows Move Continents East or Westward  	Example: All supplied animations are palaeomagnetic reconstructions in a South Africa frame (plate 701). If you want to display the data relative a fix North america, then click the row '101North America….' And engage this option. If you have a new pole from North America at this time engage 'VGP rotate' to make animation file absolute based on your new pole. Add the same Euler to all rows As above but rotating about 90 or -90 so only change longitude if animation file is based on palaeomagnetic data (calibrating longitude)
VGP Rotate  	Supplied animation file are 'absolute' but if first rotated to a continent held fix (see 'Add Euler Poles'above) then you can use a VGP from that continent to all rows in the animation file and thus make your own 'absolute' reconstruction.

The input-format in ANIMATION files is as follows:

1	CON	Name of continent (`.CON') file
2	LAT	Latitude of Euler Pole
3	LONG	Longitude of Euler Pole
4	ANGLE	Rotation angle about Euler Pole (+)=clockwise;(-)=counterclockwise
5	COMMENT	Comment (any text)

8. VELOCITY

The main purpose of this option is to calculate latitudinal drift-rates and rotational velocities for continents or terranes. This option *(old and not updated yet)* is found in 'VGP Table' and 'Tools' and options are as follows:

OPTION/SUBOPTIONS	EFFECT
Exit	Return to 'VGP Table' menu
VGP Open VGP file Merge VGP file Analysis 1: Velocity and Angular Rates Analysis 2: APW rates HPGL (write to file) 	 Open a VGP file from disk Open a VGP file from disk; displayed together with existing VGP data in subsequent graphic actions Calculate and displays palaeolatitude, drift-rates and angular rotation Calculate and displays APW Copy graphics to HPGL plotter or file
Print	
Settings 	Set system parameters that control the program performance (automatically stored during 'Exit')
Timescale Use Gradstein et al. (2004) Build your own 	 Gradstein et al. (2004) Modify timescale (auto-saved to a system file)
Polarity Bias 	

3.20.1 DRIFT/ANGULAR RATES

Based on a sequence of ordered (sorted with increasing magnetic ages) VGP poles (either original data or APW spline data) this option provides an analysis and display of palaeo-latitudes for a given reference locality (see 3.20.2) through geological time (top diagram in Fig. 16).

Analysis of APW paths:

If the VGP file contains an APW or 'spline' path (cf. 3.11.3) parameter `APW path or spline' (see 'SETTINGS'; cf. 3.20.2) and parameter 'Plot declination' should be set to on. This will produce a display as illustrated in Fig. 16 (VGP file B20092; used for Baltica by Torsvik et. al. 1992) where declinations (according to a reference locality: 60oN and 10oE in our example) are plotted along the latitudinal drift-curve (i.e. a natural cubic spline curve). Based on the setting of the `Time Window' parameter (cf. 3.20.2) this option calculates latitudinal drift-rates (in cm/y) and rotational velocities (in o/Ma). Drift-rates are automatically seperated into Northward (UPPER part of diagram) or Southward (LOWER part of diagram) movements (middle diagram in Fig. 16), whereas rotational velocities are separated as clockwise (UPPER part of diagram) or counter-clockwise (LOWER part of diagram) rotations.

Analysis of original data:

If the VGP file contains original data, the parameters `Original data' and 'Plot latitude error' (cf. 'SETTINGS'; 3.20.2) should be set to on. This produces a display as illustrated in Fig. 17 (VGP file Bal92; used for Baltica by Torsvik et. al. 1992) where palaeo-latitudes (according to the reference locality) are plotted with error bars (based on alfa95).

FIG 16 Example of option `VELOCITY' (VGP file:B20092) using an APW spline path.

FIG 17 Example of option `VELOCITY' (VGP file:BAL92) using original data.

3.20.2 SETTINGS

This option permits the adjustment of parameters which control the `Velocity' option performance. The following parameters can be changed/updated:

PARAMETER	FUNCTION

Reference latitude (in degrees) Palaeolatitudes, drift-rates and angular velocities Reference longitude (in degrees) are always calculated with respect to the selected reference locality

Start Time (in Ma) Whenever a VGP file is loaded the program tests for

End Time (in Ma) minimum (start)and maximum (end) age range, and the horizontal time-axis (see Fig. 16) is set up accordingly. The operator can, however, change the START and END times after having loaded a VGP file. Useful when combining several VGP files with different Start and End times (i.e. plot at same scale)

Time window (in Ma) Drift-rates and rotational velocities are averaged within the setting of this parameter

Invert Latitudes (Yes or No) Dependent on the choice of VGP polarity the operator may have to invert latitude estimates. E,g. file B20092 is a south-pole file and 'Invert Latitudes' has to be set to 'Yes' in order to display the latitudinal movements of Baltica correctly.

Plot Declination or Latitude error Set 'Plot declination' to ON when analysing APW paths:

Use 'Latitude Error' to include latitude error bars for original VGP data (calculate error bars from INC+□95 to INC-□95).

APW path/spline or Original data Set 'APW path/spline' to ON when analysing APW paths

Expanded Latitude plot (Yes/ No) Display of latitudinal plot (top diagram) two times normal size when set to YES

Amplitude Latitude Plot (in Deg) Set maximum amplitude (90o<value>0o)

Amplitude drift-velocity (in cm/yr) Set maximum amplitude (Value>0 cm/yr)

Amplitude rotation plot (in o/Ma) Set amplitude (Value>0 Deg/Ma)

Amplitude CUM APW (in Deg) Set amplitude (value >0o)

(used in option 'APW rates)

Amplitude APW rate (in cm/year) Set amplitude (value>0 cm/yr)

(used in option 'APW rates')