Geological-Geophysical Atlas of the Central Atlantic Ocean

Volume I
Common Geophysical and Geological Data

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Moscow
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**Data Sources**

5. ETOPO5 Set. Global Relief Data CD. NOAA Product # G01093-CDR-A0001.
17. Tectonic Map of South America. 1:5000000. DNPM-CGMW-UNESCO. 1978
22. CNSS Earthquake Composite Catalog. June 1997 (http://quake.geo.berkeley.edu/cnss/)
Scheme of Surveys and Stations at Central Atlantic Conducted by Geological Institute RAS.

Legend:
- Survey lines [1,6]
- Detailed survey lines [1]
- DSDP and GDR wells [2,3]
- Stations with hard rocks, sampled by foreign vessels (see complete reference list in explanation notes)
- Stations with hard rocks, sampled by Soviet and Russian vessels (see complete reference list in explanation notes)
- Stations with hard rocks, sampled by Geological Institute (see complete reference list in explanation notes)
- Stations with hard rocks, sampled by submarines

Geological Institute RAS, R/V "Akademik Nikolaj Strakhov"
- Cruise 1, 1984
- Cruise 2, 1984
- Cruise 3, 1985
- Cruise 4, 1985
- Cruise 5, 1987
- Cruise 6, 1987
- Cruise 7, 1988
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- Cruise 22, 1995

Vernadsky Institute of Geochemistry RAS, R/V "Akademik Boris Petrov"
- Cruise 1, 1984
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Schmidt Institute of Physics of Earth RAS, R/V "Ivan Kireev"
- Cruise 1, 1978
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- Cruise 34, 1997
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- Cruise 36, 1998
- Cruise 37, 1999
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- Cruise 40, 2000

List 1.

Scale 1:20000000 by Equator

Sokolov S.Yu., Mazurovich A.O., Efimov V.N.
2000
Physical-Geographical Map of Central Atlantic.

Legend
- ▲ seamounts names, approved by GEBCO commission
- ▼ seamounts without official names including digitized from altimetry data [4]

The regions of Cape-Verde Islands and Bathymetrist seamounts are shown on altimetry data [4] at the scale 1:7700000.
Geographic names are shown on the basis of International Gazetteer, dictionaries and atlases [7,8,9,10].

Bottom Topography of Central Atlantic from Satellite Altimetry Data and Topography of Adjacent Continents.


Commentaries
Topographic base map is shown by satellite altimetry data on 2 arc minute grid [11] and GTOPO30 [13]. Hydrographic net is shown by ESRI data [14].
Joint Free Air Gravity Field Anomalies of Central Atlantic and Adjacent Continents

List 4. Sokolov S.Yu. 1998

Joint anomalies are shown by satellite altimetry data [4] on 2 arc minute grid and by EGM96 data [12] on 30 arc minute grid for land areas. EGM96 data with precision of oceanic areas reduced to 30 arc minute are shown on insertion within extents of main base map in scale 1:77000000.

Commentaries:

Joint anomalies are shown by satellite altimetry data [4] on 2 arc minute grid and by EGM96 data [12] on 30 arc minute grid for land areas. EGM96 data with precision of oceanic areas reduced to 30 arc minute are shown on insertion within extents of main base map in scale 1:77000000.
The Structure of Sedimentary Cover of Central Atlantic.

List 5. The Structure of Sedimentary Cover of Central Atlantic.

Sokolov S.Yu., Mazarovich A.O., Efimov V.N.

Cartographic base of this list is created from ETOPO5 data [5] with depth contours interval of 1000 m (500 m from 3 to 6 km, minimum contour - 200 m). Sedimentary cover thickness is performed on the base of digital models, created after data of B. Tucholke and E. Uchupi [25]. Rock types and ages of sedimentary samples are performed: for wells - after data of [2,3]; for piston cores - after data of [27]; for dredges - after expeditions material (see Explanation Notes). Distribution of average velocities of P seismic waves propagation for layers from 0 to 2 km and from 2 to 5 km is shown on insertion in scale of 1:11000000 after data of [26].
Mesozoic-Cenozoic Magmatism and Crust Age of Central Atlantic

List 6.
Mazarovich A.O., Sokolov S.Yu., Dobrolyubova K.O.
©2000

Geological time scale (Ma)

Legend
- active hydrothermal vents
- active volcanoes and the date of recent explosions
- locations of stations with fresh glasses

- absolute age definitions
- Early Mesozoic dolerites
- Quaternary effusive rocks

Common mapbase is made by data of satellite altimetry [11] and GTOPO30 [13]. Oceanic crust age isochrons are made by data of magnetic linear anomalies interpolation [15]. The areas of volcanites development are digitized from [16,17]. Locations of seamounts are digitized from altimetry data [4]. Hydrothermal vents locations are shown by data [28].
Seismicity, Heatflow and Magnetic Anomalies of Central Atlantic.

Legend and Commentaries
Cartographic base of this list is created from predicted topography data of satellite altimetry [11] and GTOP030 [13] (see List 3). Magnetic anomalies lineations are shown after [21]. The numbers at the begin and end of each lineation mark it's order number according to international classification. Earthquakes data were extracted from composite catalog CNSS [22] on June 1997 (2258 events). The epicenters of events are shown by three depth ranges of hypocenter, and also respect to event magnitude in the range from 3 to 7 by variation of linear size of symbols:

- 0-13 km
- 13-40 km
- >40 km

The heatflow data are shown after [23] and data of authors by three value ranges (mW/m²):

- 0-40
- 40-70
- >70

The insertion within extents of main base map in scale of 1:77000000 shows the Z component of magnetic anomalies from CHAMP data [24] of 2002 recalculated from 450 km to Earth surface on 15'x15' grid.

Sokolov S.Yu., Podgornykh L.V. (VNIIOkeangeologiya), Khutorskoy M.D. (RUDN) ©2004
Earthquakes Focal Mechanisms, Slip Vectors and Geoid Surface of Central Atlantic.

Commentaries

The cartographic base for this list is made from satellite altimetry data [4] and EGM96 data [12] (see List 4). Geoid surface isolines are shown by 5 meters after the data of joint NASA and DMA project [18], which is part of EGM96. On insertion within extents of main base map in 1:77000000 scale is separately shown the geoid surface relief. The earthquakes focal mechanisms were taken from Harvard University CMT catalog [19] including July 2001 (348 events). Visualization of slip vectors and focal mechanisms were done by the RAKE software [20] without scaling of symbols by events magnitude. On insertion with shaded relief ofETOPOS [5] within extents of main base map in 1:77000000 scale are shown the mechanisms of stress discharge by WSM data [29].

List 8.

Scale 1:20000000 by Equator
Commentaries

Bouguer anomalies estimation was made on basis of satellite altimetry data [4], averaged to 5 arc minute grid, and bathymetry data [5], combined from digital data of GEBCO and survey results into ETOPO5 grid, smothed by 10 km radius window for elimination of high frequency noise of digitized GEBCO isolines. Topographic reduction was calculated under following parameters:

- $R = 166$ km
- Oceanic crust specific gravity - 2.75 g/cm$^3$
- Continental crust specific gravity - 2.67 g/cm$^3$
- Water density - 1.03 g/cm$^3$

Estimation of anomalies for joint ocean and continental EGM96 data [12] on 30 arc minutes grid was made by model of layer. The results are shown on insertion within extents of main base map in scale 1:77000000.
Bouguer Anomalies Calculated from Altymetry and Bathymetry Data on 5'x5' Grid with Correction by the Sedimentary Cover Effect.

Bouguer anomalies estimation with correction by the sedimentary cover effect was made on basis of regular Bouguer anomaly (see list 9) on the 5 arc minute grid. Calculation of sedimentary cover low masses effect in comparison to igneous part of the crust was made on the basis of B. Tucholke and E. Uchupi [25] data on sedimentary cover thickness and data on crust age [15] obtained by interpolation of magnetic linear anomalies. Also were estimated layer velocities at the bottom of sedimentary cover by Faust algorythm $V_{lay} = 46 \times \text{pow}(Z_T^{1/6})$, where $Z$ - depth (meters), $T$ - age (years). Low values of velocity were cut by level of 1500 m/s. Next step consisted of average velocity estimation for total sedimentary unit $V_{av} = 1500 + (V_{lay} - 1500)/2$, under assumption of linear law of velocity function from top to bottom of sedimentary cover. Obtained average velocities were used for calculation of average densities as $R_{sed} = 0.000357V_{av} + 0.965$. Final reduction of regular Bouguer anomalies by sedimentary cover effect was estimated as $dG = 0.0419(2.75 - R_{sed})H$, where $H$ - sedimentary cover thickness. The reduction has positive value. The data on sedimentary cover thickness of more than 500 meters are shown on the insertion within extents of main base map in scale 1:7700000.
Isostatic Anomalies Estimated from Altimetry and Bathymetry Data on 5'x5' grid by Airy model

Commentaries

Isostatic anomalies estimation was made on basis of satellite altimetry data [4], averaged to 5 arc minute grid, and bathymetry data [5] by Airy model after estimation of regular Bouguer anomalies. Estimation was made with following parameters:

- $T = 33$ km
- $R = 166$ km
- Oceanic crust density - 2.75 g/cm$^3$
- Continental crust density - 2.67 g/cm$^3$
- Mantle density - 3.15 g/cm$^3$

Estimation of anomalies for joint ocean and continental EGM96 data [12] on 30 arc minute grid was made with $R = 166$ km. The results are shown on insertion within extents of main base map in scale 1:77000000.
List 12.

Basement Rocks of Central Atlantic from Dredge Stations.

Commentaries

Map presents the results of dredging at 789 stations, which were managed during cruises of the following research vessels: Agulhas; Akademik Boris Petrov; Akademik Kurchatov; Akademik Mstislav Keldysh; Akademik Nikolaj Strakhov; Akademik Vernadsky; Antares; Argo; Atlantis-II; Chain; Dmitry Mendeleev; Eastward; Endeavor; Maurice Ewing; Pillsbury; Professor Kurentsov; Professor Stockman; Robert Conrad; Shackleton; Thomas Washington; Trident; Vema; Vityaz.

References on primary information sources are listed in Explanation Notes.
List 13.

Alternations of Basement Rocks of Central Atlantic and Its Rare Types.

Map presents the results of dredging at 789 stations, which were managed during cruises of the following research vessels: Agulhas; Akademik Boris Petrov; Akademik Kurchatov; Akademik Mstislav Keldysh; Akademik Nikolaj Strakhov; Akademik Vernadsky; Antares; Argos; Atlantis-II; Chain; Dmitry Mendeleev; Eastward; Endeavor; Maurice Ewing; Pillsbury; Professor Kureniov; Professor Stockman; Robert Conrad; Shackleton; Thomas Washington; Trident; Vema; Vityaz.

References on primary information sources are listed in Explanation Notes.

Legend
- metamorphized basalts
- metasomatic rocks
- alkaline rocks
- amphibolites, amphibolized rocks
- hydrothermal alternations
- sulfides
- shales

Scale 1:20000000 by Equator
Tectonic Map of Central Atlantic.

List 14.

Oceanic Crust Age from Magnetic Anomalies [15]

Scale 1:20000000 by Equator

1999 Mazurovich A.O., Dobrolyubova X.O.
Distribution of basic petrological types of oceanic rifts tholeite basalts (TOR), seismic S-wave tomography and their correlation with free air gravity anomalies at the area of Central Atlantic Ocean

Commentaries
Cartographic base map is computed from data of seismic S-wave tomography for the layer from 0 to 100 km [30], shaded by data of satellite altimetry [4]. Isolines of velocity variation are drawn by 0.5 % step. Classification of petrological types of oceanic rifts tholeite basalts (TOR) is made on 2080 microanalysis of glasses from GEOKHI RAS database using the methodic of cluster analysis by K-means application [31] (see legend).

Spreading association - ČLɈɊ-2, ČLɈɊ-Na.

Insertion shows the correlation between free air gravity anomaly [4], Bouguer anomaly (see. List 9) and productivity of magmatism, expressed through the thickness of basaltic layer, calculated using Na8 parameter [32, 33].

List 16. ©2005
Dmitriev L.V. (GEOKHI RAS), Sokolov S.Y., Plechova A.A. (GEOKHI RAS), Sokolov N.S. (MSU)

Scale 1:20000000 by Equator
Commentaries
Calculation of mantle Bouguer Anomalies with correction effects of sedimentary cover and total depth of mantle beneath the sea level was done from normal Bouguer anomalies with sedimentary cover effect (see List 10) on 5'x5' minute grid. For the calculation of effect of mass waste above Moho discontinuity its hypsometric position was described as stacked sea bottom relief, sedimentary thickness and assumed thickness of oceanic crust as 6000 meters. While this it was also assumed, that water layer and sedimentary cover are already filled to crust average specific gravity, and the space above Moho has uniform oceanic crust density. Then the calculation of reduction was made by formula of layer dG = 0.0419*(0.5)*H, where H - total depth value of Moho, 0.5 g/cm³ - the density difference between crust and mantle. The reduction has positive value. The total depth data of Moho are shown on the insertion within the limits of main map frame in scale 1:77000000.
Commentaries

Regional component of mantle Bouguer anomalies with correction effects of sedimentary cover and total depth of mantle beneath the sea level (see List 17) was calculated by spatial filtration in 65 km moving window. The choice of window size was approved by the presence of minimum in power spectrum of primary filed around this value of wave length. Regional component derived as a result of low frequency filtration reflects the variability of upper mantle density. Conditional depth level of calculated anomalies - about 20 km and deeper.

Insertion within the limits of main map frame in scale of 1:77000000 shows the S-wave velocity variations in 0-100 km layer from [30]. The comparison of regional mantle Bouguer component and of the seismic tomography data provides general coincide of heated and partially melt zones of upper mantle in gravity and seismic tomography data.
List 19. Sokolov S.Yu., Mazarovich A.O.

Commentaries
Local component of mantle Bouguer anomalies (residual field at wavelength less than 65 km) was calculated as a result of subtraction from full spectrum mantle Bouguer anomalies (see list 17) the result of low frequency filtering of this field by the averaging window of 65 km diameter (regional component, list 18). Conditional depth level of calculated anomalies - less than 20 km. Insertion within the limits of main map frame in scale of 1:77000000 shows the places of methane plumes, ultramafic rocks and the rocks with the presence of serpentinization after (see list 12).
Conventional density variations in crust layer.

**Commentaries**

Conventional density variations in crust layer are the results of correlation coefficient calculation between the bottom topography and Bouguer anomalies in area of 30 km radius for each point of 5x5 grid. Calculation was made using the method from [34], and includes the iteration by density values from 1 to 6 g/cm³ while calculation of correlation for each point. The calculation was fixed when correlation value had transition through zero value. This values indicates density, at which the fill of absent masses into water layer optimally compensate the effect of bottom topography. Obtained values are proportional to density structure of the crust but are not exactly the values of density, so they are considered as conventional values.

This method of density variation calculation mainly shows the density contribution to Bouguer anomaly, depends less from thickness variation and has reduced uncertainty between density and crust thickness. The algorithm is based on the correlation between relief and gravity contrast of water-basalt layers, and in case of the basalt irregularities filled by sediments starts to show specific artifacts.

In connection to this the area where average sedimentary thickness exceeds 200 meters from the data [25] is shows darkened on the map. Conventional depth range for calculated anomalies is about 10 km. Insertion within the limits of main map frame in scale of 1:77000000 shows the places of methane plumes, ultramafic rocks and the rocks with the presence of serpentinization after (see list 12).

List 20. ©2013 Sokolov S.Yu., Mazurovich A.O.

Scale 1:20000000 by Equator
Sokolov S.Y.

Horizontal gradient of gravity isostatic anomalies (List 11), calculated from X and Y components and final module on the base of 3 nodes of original grid on 5'x5' step (18 km).

Insertion with the limits of main basemap shows earthquake epicenters from [22] data in scale 1:77000000.
List 22. Sokolov S.Yu.

Vertical Deflection Module of Gravity Force Vector

Comments
Vertical deflection module of gravity force vector calculated from X and Y components with following module estimation from primary deflection grids on 2'x2' (3.7 km) from data [35]. Insertion with the limits of main basemap shows GPS time series vectors from data [36] in scale 1:77000000.
Anomalous Magnetic Field

List 23.

Sokolov S.Yu.

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Anomalous magnetic field from [37] on 2°x2° grid. Areas without values are painted yellow. Insertion with the limits of main basemap shows phase velocity variations of Love waves of 35 s period from [38] in scale 1:77000000.

Magnetization, calculated on 2'x2' grid from data of anomalous magnetic field [37], stacked bottom depth [1] and sedimentary cover thickness [25] as a distance to top of magnetized rocks by sphere expression for 0.5 km layer and inclination angle of 45 degrees.

On the insertion within the limits of main basemap is shown lithospheric model of magnetic field MF3 from satellite data of CHAMP [39], calculated as analytical signal (full gradient module) of dT in scale of 1:77000000.

Comments
Magnetization, calculated on 2'x2' grid from data of anomalous magnetic field [37], stacked bottom depth [1] and sedimentary cover thickness [25] as a distance to top of magnetized rocks by sphere expression for 0.5 km layer and inclination angle of 45 degrees.

On the insertion within the limits of main basemap is shown lithospheric model of magnetic field MF3 from satellite data of CHAMP [39], calculated as analytical signal (full gradient module) of dT in scale of 1:77000000.
List 25. Sokolov S.Yu.

Acoustic Basement and Deep Seismic Sounding Data

Comments
Acoustic basement is calculated on 5'x5' grid from bathymetry data GEBCO [1], smoothed to 5-min grid, and sedimentary cover thickness [25]. The data of deep seismic sounding (DSS) presented from [10,40].

Insertions shows generalized DSS data sections for numerated profiles across equatorial segment (1) and Angolo-Brazilian geotraverse (2). Numbers above points are the refraction velocities from M border, red numbers below points are the depths to M border.
Thickness of sediments between bottom and reflection horizon D (~25 Ma) and linear magnetic anomalies

Comments
GBECO bathymetry [1] on 30°X30° grid, linear magnetic anomalies [21] and sedimentary thickness between bottom and reflection horizon D (~25 Ma) [41]. Insertion within the limits of main basemap shows horizontal slice of the cube with variation of Vp/Vs attribute at 470 km, calculated from seismic tomography data for P and S wave from [42] in scale of 1:77000000.
Thickness of sediments between reflection horizons D and Ac (from ~25 Ma to ~49 Ma) and linear magnetic anomalies

Comments
GEBCO bathymetry [1] on 30°x30° grid, linear magnetic anomalies [21] and sedimentary thickness between reflection horizons D and Ac (from ~25 Ma to ~49 Ma) [41]. Insertion within the limits of main base map shows horizontal slice of the cube with variation of Vp/Vs attribute at 470 km, calculated from seismic tomography data for P and S wave from [42] in scale of 1:77000000.
Thickness of sediments between reflection horizons Ac and A* (from ~49 Ma to ~68 Ma) and linear magnetic anomalies

List 28. Sokolov S.Yu.

Comments
GEBCO bathymetry [1] on 30°x30° grid, linear magnetic anomalies [21] and sedimentary thickness between reflection horizons Ac and A* (from ~49 Ma to ~68 Ma) [41]. Insertion within the limits of main basemap shows horizontal slice of the cube with variation of Vp/Vs attribute at 470 km, calculated from seismic tomography data for P and S wave from [42] in scale of 1:77000000.
Thickness of sediments between reflection horizons A * and β
(from ~68 Ma to ~112 Ma) and linear magnetic anomalies

Legend
- Chron (ID)
- 0 m
- 50 m
- 100 m
- 200 m
- 400 m
- 500 m
- 600 m
- 800 m
- 1000 m
- 1200 m
- 1400 m
- 1500 m
- 1600 m
- 1800 m
- 2000 m
- 2200 m
- 2500 m
- 3000 m
- 3500 m
- 4000 m
- 4500 m
- 5000 m
- 5500 m
- 6000 m
- 6500 m
- 7000 m

Comments
GBECO bathymetry [1] on 30°×30° grid, linear magnetic anomalies [21] and sedimentary thickness between reflection horizons A* and β (from ~68 Ma to ~112 Ma) [41].
Insertion within the limits of main basemap shows horizontal slice of the cube with variation of Vp/Vs attribute at 470 km, calculated from seismic tomography data for P and S wave from [42] in scale of 1:77000000.

List 29. ©2016 Sokolov S.Yu.

Scale 1:20000000 by Equator
Thickness of sediments between reflection horizons $\beta$ and J (from $\sim$112 Ma to $\sim$129 Ma) and linear magnetic anomalies

**Legend**
- Chron (ID)
- 0 m
- 100 m
- 200 m
- 400 m
- 500 m
- 600 m
- 800 m
- 1000 m
- 1200 m
- 1400 m
- 1500 m
- 1600 m
- 1800 m
- 2000 m
- 2500 m
- 3000 m
- 4000 m
- 5000 m
- 6000 m
- 7000 m

**Comments**
- GEBCO bathymetry [1] on 30'x30' grid, linear magnetic anomalies [21] and sedimentary thickness between reflection horizons $\beta$ and J (from $\sim$112 Ma to $\sim$129 Ma) [41]. Insertion within the limits of main basemap shows horizontal slice of the cube with variation of $V_p/V_s$ attribute at 470 km, calculated from seismic tomography data for P and S wave from [42] in scale of 1:7700000.

**List 30.** Sokolov S.Yu.
Thickness of sediments between reflection horizon J and acoustic basement (from ~129 Ma) and linear magnetic anomalies

GEBCO bathymetry [1] on 30°x30° grid, linear magnetic anomalies [21] and sedimentary thickness between reflection horizon J and acoustic basement (from ~129 Ma) [41]. Insertion within the limits of main basemap shows horizontal slice of the cube with variation of Vp/Vs attribute at 470 km, calculated from seismic tomography data for P and S wave from [42] in scale of 1:77000000.
Cluster combinations of geophysical parameters with geodynamical interpretation

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<td>15</td>
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Comments
GEBCO bathymetry [1] on 30°x30° grid and cluster combinations of geophysical parameters, having geodynamical interpretation from [43]. Insertion contains table with mean values and dispersion of parameters used for calculation for each of 15 detected cluster combinations.