مجلة العلوم البحثة والتطبيقية
Journal of Pure & Applied Sciences
www.Suj.sebhau.edu.ly ISSN 2521-9200
Received 03/06/2016 Revised 07/11/2016 Published online 16/10/2017

Detection of Rifted Continental Margin from Satellite Gravity Data

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Abstract The principle to understand of plate tectonics is presumably which so-called rifted continental margins formation. To determine the structure and formation processes of the rifted margins, recent observation of mantle exhume has been observed which associated with the production of anomalies thin ocean crust- depth dependent lithosphere extension at rifted margin has revolutionized our knowledge of structure and process that form rifted margin. The new quantitive of satellite gravity data will be used to emphasis this idea. Recent finite element modeling of formation of passive rifted margins suggests that differentially stretching occurs during early sea-floor spreading generating transitional continental oceanic boundary, exposing continental mantle material at the surface. Its documented along present day and ancient passive continental margins where it occurred during the final rifting stage during break-up of the continental lithosphere. The key to understanding mantle exhumation at ocean ridges is the coupling of fault exhumation and the production of thin ocean crust at slow spreading ridges.

key word: Continental margin from satellite.

شكل الحيود القارية باستعمال معطيات الجاذبية من بيانات الأقمار الاصطناعية

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الملخص إن أساس فهم النظرية التكتونية (إزاحة القارات) هو تكون الحيود القارية. فقد أوضحت المشاهدات الحالية، ومن خلال تقييم عملية تكون وتركيب هذه الحيود ، بان مواد (صخور) الوشاح mantle هي ارتباط لوجود طبقة رقيقة نسبيا (شاذة) والمتوضعة تحت المحيطات . وإن عملية الشد التي تحدث خلالها هي لتأكيد معرفتنا لكل من التراكيب والعمليات المسئولة لتكون هذا النوع من الحيود. وفي وقتنا الذي نعيش فيه وفي توفر إمكانية الاستفادة من عصر الفضاء (الأقمار الاصطناعية) باستعمال معطيات الجاذبية في ذلك . إن نماذج المحاكة (الافتراضية) Modeling لتكون هذا النوع من الحيود أوضحت بوجود معدلات مختلفة للشدة Stretching في الطبقات وذلك خلال بدايات مرحلة تباعد Spreading الحواف الأرضية أوجدت حد فاصل بين نوعي القشرة (الأرضية والمحيطية) انبثقت منه مواد الوشاح على السطح ، وهي إشارة لحاضر وماضي للحيود القارية أين حدثت خلال مراحل النهائية لتصدع Break up الغلاف القاري . إن المدخل لفهم وجود مواد الوشاح عند الحواف هي ازدواج الصد وع Faults والتي بدورها أوجدت الطبقة الرقية الموجود عند تباعد الحواف خاصة ذات المعدل البطيء في تباعدها.

الكلمات المفتاحية: الحاف القاري من القمر الصناعي.

1.Introduction:

According to the plate tectonic theory, the outer self of the earth is covered by small numbers of rigid lithospheric plates, which a relative motion with respect to other, in response to force (stresses), on their interiors, the relative velocity of the plates are of the order of a few tens of millimeters per years. The principle to understand of plate tectonics is presumably which so-called rifted continental margins formation. Rifted continental margins are associated with material discontinuity and development of new oceanic crust at sea-floor spreading center. A hot mantle rock cools near surface it becomes rigid and accretes to the plates, creating new plate area. As the rock of the lithosphere becomes cooler, their density increases because of thermal contraction. However the margins of plate can be grouped into three varieties as, Shear, Accreting, and Consuming margins.

The lithosphere layer of the earth is composed of two forms, continental and oceanic crusts, and the region along the edge of the continents, were they meet are known as continental margins. The outstanding question of how continental lithosphere plates thin and break forming oceanic basin between them has been fundamental problems in earth sciences. The transition between thick (quartz- feldspar) continental to thin (basalt-gabbro) oceanic crust, these transition zones define the fundamental components of the plate tectonic cycle. The interactive nature and complexity of these processes has been recognized, as has the need for collaborative studies to address them. This article focus on rifted margin those formed when a continent split a part, allowing new oceanic crust to form in the gap. Perhaps the North Atlantic region contain of the best known example of the process which include, Labrador Sea and Iberian margins, because these region have been extensively studied and surveyed geologically and geophysicaliy by many authors [1]. Detail seismic reflection and refraction measurements [2] would greatly benefit in corporation between academia and industry exploration, to provide answers of the process of rifted margins across the margins.

The theory of plate tectonic provides a conceptual framework within which the flow and composition of the oceanic mantle is related to crustal and lithospheric processes. At mid-ocean ridges, upwelling mantle undergoes decompression melting forming new oceanic crust and chemically depleting the upper mantle. Chemical and thermal heterogeneities, formed at spreading centers and altered during tens of millions of years ago and horizontal plate motion. Rifted continental margin is associated with material discontinuity and development of new oceanic crust at sea-floor spreading center. The new oceanic crust, which generate not only must fill the space generated between two constructive plates, but the melt must expose at the surface. However rifted margins have traditional been assumed to form by extreme extension at high stretching factor,[3]. And pressure-temperature-time histories of some of the core have also provided constrains of the rates of extension and exhumation. The rift subsidence is considered as consequence of thermal contraction of the lithosphere as a heat source migrate away from the margin after the onset of sea-floor spreading. Heat flow measurement may potentially be used to study the mode of extension at rifted continental margins and basins that have only small residual heat flow anomalies, which related to rifting. For this [3] shows that, the heat flow of continental rift is consequence to two major compending effects, first , lithosphereric thinning, second, lithospheric stretching.

2- Material and Methods

While the uniform stretching model [4] and its derivatives have been applied with considerable success to the formation of intercontinental rift basin, the mechanism for the formation of rifted continental margins is at best controversial. Rifted margins have traditionally been assumed to form by extreme extension and thinning of continental lithosphere [5]. Ultimately this well be leading to the initiation of seafloor spreading at high stretching factor.

Crustal thickness variation along rifted continental margins is assumed to be the consequence of crustal extension and thinning and is used to infer the lateral distribution of strain. the crustal derived stretching factor is

$$\beta = \frac{t_0}{t_c}$$

In which (t_0) is the pre-stretching continental crustal thickness; (t_c) is total present day crustal thickness.

It is convenient to define the thinning factor (ε), which is related to the stretching factor by equation

$$\varepsilon = \left(1 - \frac{1}{\beta}\right)$$

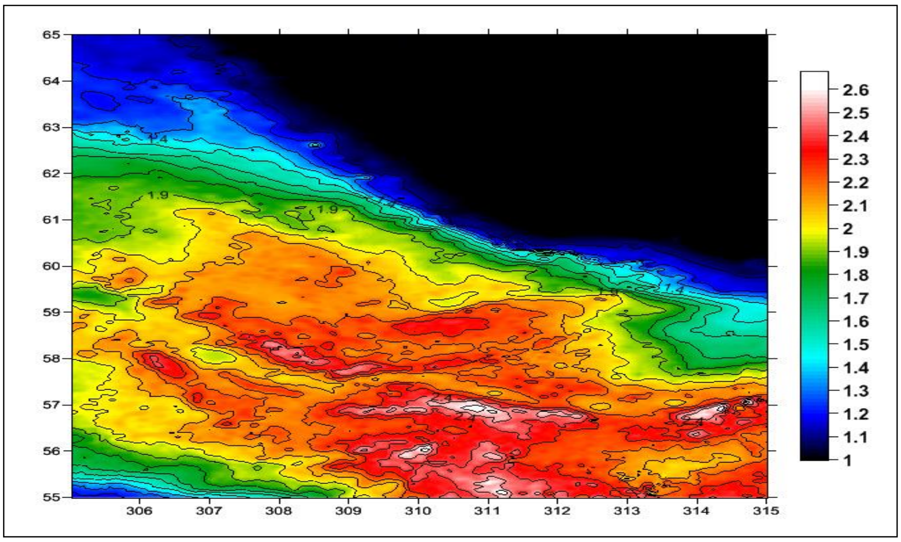


Fig. 1. Result of beta Factor of SW Greenland

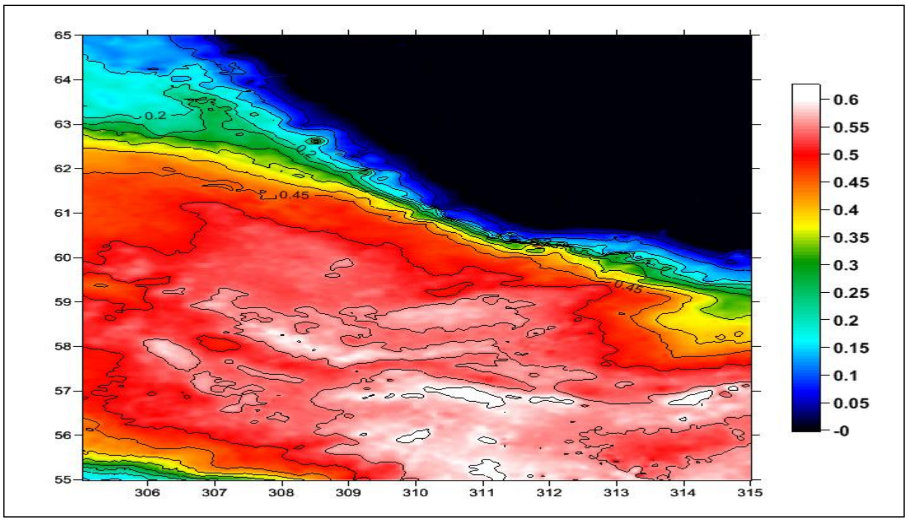
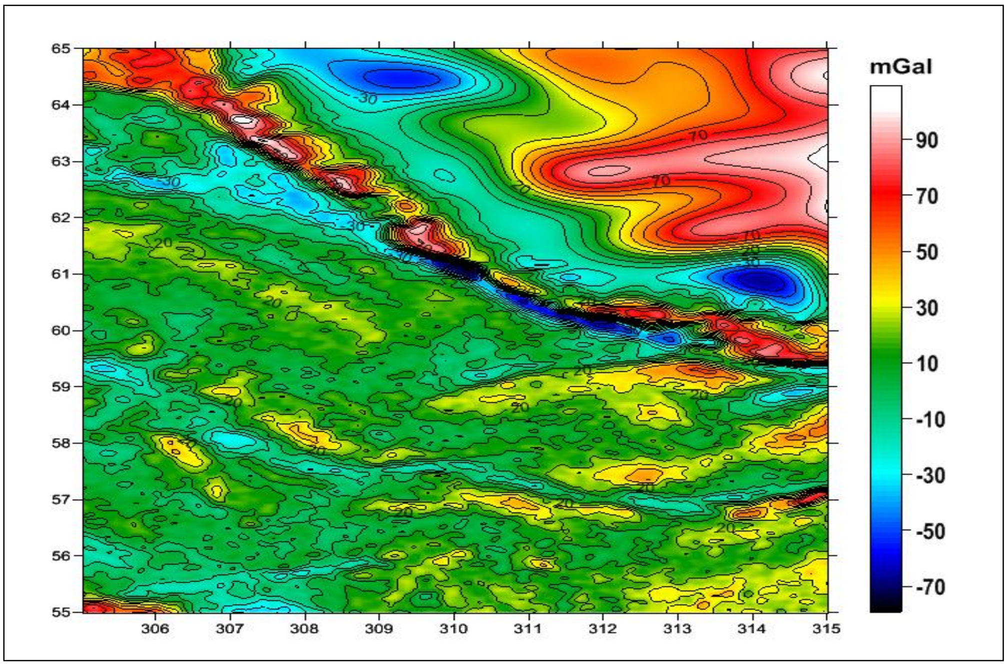


Fig. 2. Show Result of Thinning (Extension) Factor related to Beta Factor of SW Greenland

There is a substantial evidence that the modes of lithosphere extension at slow rates rifting the continental crust expose regions of serpentinize mantle with little evidence of molten leading to the formation of non-volcanic margins and sedimentary basins has focused on pure shear versus simple shear [6],[7] ,[8]. Earlier studies on SW of Greenland shows, these margins structure are usually observed in multi- channel seismic reflection data to have thinned block fault crust covered by thick sedimentary layers [9] and a peculiar feature of nonvolcanic rifted continental margins in the North Atlantic are shows that, the lower crust in the vicinity of the transition from thinned continental crust to oceanic crust exhibits anomalously high seismic velocity of $\left(7.2-7.9 km/s^{-1}\right)$. Such velocities are not typical either of normal oceanic crust or of continental crust [10]. Paradioxally all rifted margins appear to be "upper plate" in term of detachment model [11] exhumation of continental mantle.

2 -1: Satellite Gravity:

The gravity maps small distortions in the earth's gravitational field; these distortions are result from, change in density structure at the seabed and deeper due to presence of different rock types. Near surface bathymetry generates major density boundary between rock and water and this tends to dominate the gravity signal. However the earth gravity field is the fundamental physical force for every dynamic process on its surface, and interior as well. The launching of the space age the determination of the global gravity field has been seen as major task. It's characterized by combination of satellite geodetic and gravity methods. Its result significantly improved measurement, and will aid the determination of global gravity field with constraint accuracy and higher resolution in geophysical research [12] . It's currently recognized by several major oil companies as a new important prospecting tool for cost-effective mapping of the marine gravity field in remarkable detail [13]. Some major oil companies have already incorporated satellite gravity in their exploratory work, it's images permit structural geologists to identify thick sediment accumulation, and it images are increasing being used to optimize the layout of detailed seismic programs to some extent support the interpretation, however satellite gravity relies on the fact that change in sea surface height are related to the existence of local gravity anomalies [14]. Satellite based radar altimeters offer the opportunity to measure the sea surface height to a precision of few centimeters. (Fig. 3).



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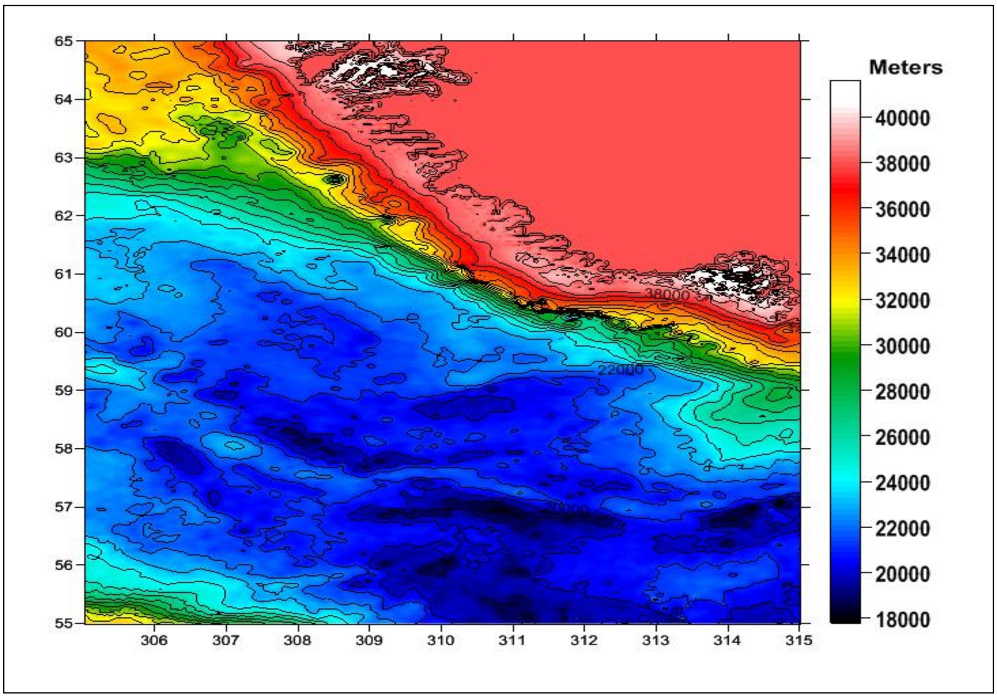

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Fig. 3. Shows. (A) Free Air Gravity of The region of SW Greenland, (B) Crustal thickens of SW Greenland based on Gravity inversion

2-2: Effect of Free-air gravity :

The free-air gravity “edge effect” anomaly associated with passive continental margins is one of the most distinctive features of the marine gravity field. The edge effect to the transition between thick continental crust and thin oceanic crust [3]. Meanwhile thinning of the crust during continental breakup is still regarded as major contributor, it is now recognized that geological processes such as sediment loading and magmatic underplating significant modify the free-air gravity [3]. In recently acquired seismic reflection profile, and gravity data will enhance to better understanding the there are two approaches with gravity first forward modeling, second inversion origin of the edge effect anomaly at the rifted margin of north Atlantic continental margins and other. Combined 2-D backstriping and gravity modeling techniques were used to restore the crustal structure at the time of rifting, to determine the subsidence, to quantify the contribution of sediment and magmatic loading to modification of the crustal structure after rifting take placed. Since previous studies indicate that oceanic and continental lithosphere respond differently to loading, [15]. This properties were used to determine the degree of along-strike structural segmentation, the spatial distribution of extended continental crust and, where possible the location of the ocean-continent boundary at the Greenland margin.

2-3: Numerical Modeling:

The manner of geodynamic modeling is being increaslly used to support the our understanding of the formation of rifted continental margins, and the processing which should have been used over complex structure areas interesting, and more useful for modeling to establish and portray to define processing parameters can be tested against observation and provide the basis for design of new experiments, most significant behind the development of many geodynamic modeling is also need to understand the formation, thermal history, and subsidence of sedimentary basins. Corner flow of a viscous incompressible fluid has often been used to portray the flow of the mantle material near spreading center. As these regions of mantle are partially molten, a better approximation is to examine the two-phase corner flow, [16]. In recent years, many models of flow in the upper mantle beneath the oceans have been developed include upwelling and swell formation of mantle flow and melt migration beneath fast and slow spreading centers. These models have been based on and designed to explain observation of features at the earth surface, such as bathymetry, gravity, plate kinematics and the composition of the melt products of upwelling beneath ocean ridges, although much progress has been made on developing tomographic of seismic structure. The purpose of this article is to test new models of rifted margins formation to illustrate how the consequent of oceanic mantle at slow spreading ridges progressively exhumed.

2-4: Temperature Modeling:

Two Dimensional (2-D) finite difference model of rifted continental margins, use to investigate some simple physics and to examine the influence of some rheological condition. That is important to the used model to predict the gravity anomalies and vertical motion observed at ridge, the 2-D, thermal numerical models have been developed to investigate behavior and effect of rifted margin interaction on the gravity. The governing 2-D equation for the conservation of energy was solved to predict the temperature "T" as function of variables Time 't', horizontal position 'x' and depth 'z'. The thermal behavior within the spreading ridge can describe by the heat transport equation. The effect on mantel temperature of conductive heat loss during extension at a finite rate is illustrated in figure (4). The governing equation for conservation of heat with isotropic thermal condition and advection(ignoring radiogenic heating) is found by solving the advection-diffusion equation

$$\rho c\left[\frac{\partial T}{\partial t}+V.\nabla T\right]=\nabla.(K.\nabla T)+H \qquad (1)$$

Which, if thermal diffusivity is constant becomes

$$\frac{\partial T}{\partial t}=\chi\nabla^2 T-V.\nabla T \qquad (2)$$

Where

T = Temperature
t = Time
χ = Thermal diffusivity , $\chi = k/\rho c$
H = Heat source in upper part of lithosphere

Equation (2) can be solved by using 2-D explicit forward finite difference technique, with center difference for the conduction term, and upwind difference of the advection term.

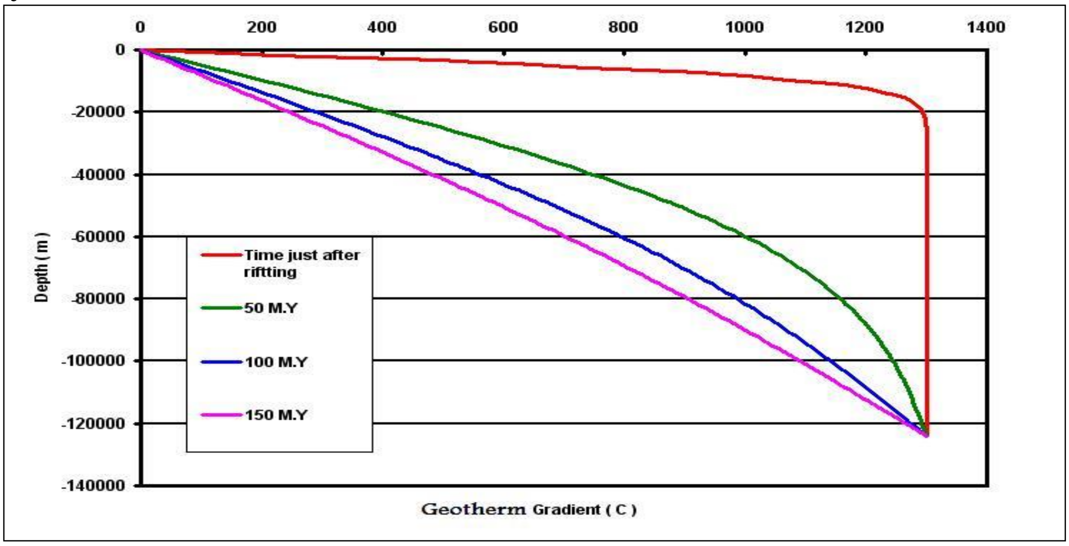


Fig.4. the Geothermal plotted every 50 M.Y. the Red curve marks the Geothermal after instantaneous extension.

2-5: Corner Flow:

Numerous numerical modeling techniques could be used to model flow vector (finite element, finite difference, and finite volume) but the chosen for this study is finite element techniques, this technique use to predict the thermal structure of spreading center and subduction zones. In order to investigate the influence into the origin of the fluid flow field at mid-ocean ridge spreading center. A simple 2-D corner flow model for iso-viscous incompressible asthenosphere mantle in which fluid upwells beneath the ridge before spreading laterally as the lithospheric plates diverge is illustrated in figure (6).
The analytical solution for corner flow is given by [17]. As The stream functions (φ) for the corner flow geometry it is possible to write in form

$$\varphi = (A_X + B_{Y0}) + (C_X + D_{Y0}) * a\tan(Y_0 / X)$$

$$U_X = -B - D\arctan\left(Z/X\right) + (C_X + D_Z)\left[\frac{-X}{X^2 + Z^2}\right] \quad (1)$$

$$V_z = A + C\arctan\left(Z/X\right) + (C_x + D_z)\left[\frac{-Z}{X^2 + Z^2}\right] \quad (2)$$

where A, B, C, and C are constants whose values are determined by boundary conditions, V and U are vertical and horizontal Velocities, the velocities components corresponding to Stream function. And Z is original thickness of crust before stretching . X is distance from ridge

$$A = 0 \quad (3)$$

$$B = -(U_x + 1) \quad (4)$$

$$C = \left(2/\pi\right)(V_z + D) \quad (5)$$

$$D = \left(-2/\pi\right)(B) \quad (6)$$

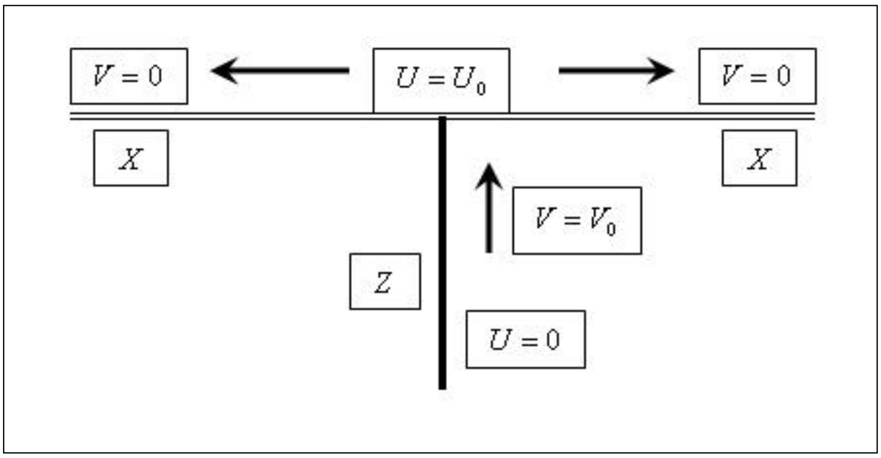


Fig. 5. Physical model for the time dependent stretching of continental lithosphere.

The previous model which shows in figure (4) takes account of vertical heat conduction. In figure (6) now consider the effect on melt generation of horizontal heat conduction using solution of corner flow.

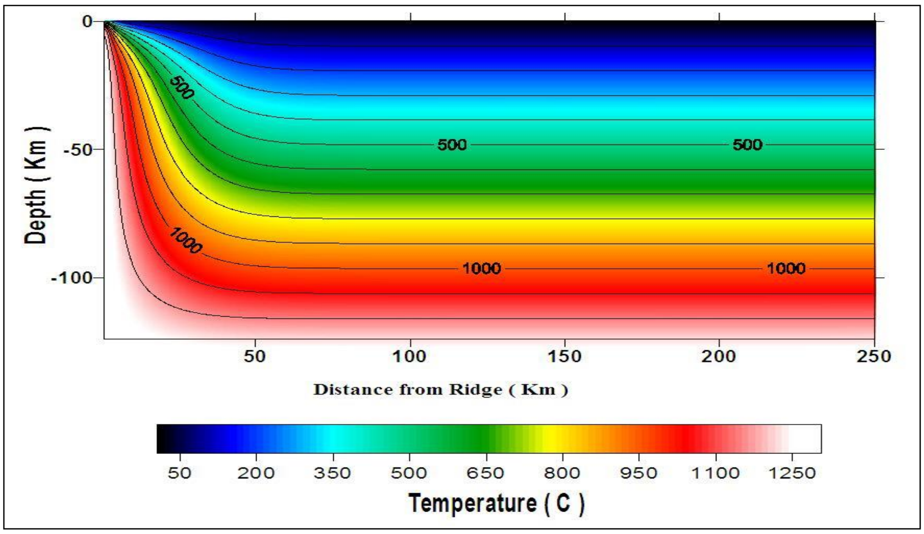


Fig. (6). 2-d model for gradient heat flow using solution of corner flow

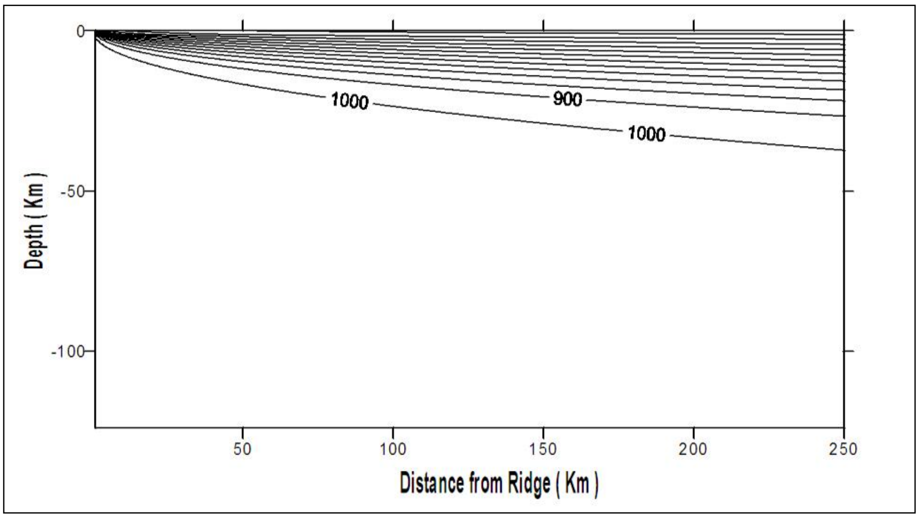


Fig. 7. The Gradient of Temperature at Rifted Margin using numerical solution

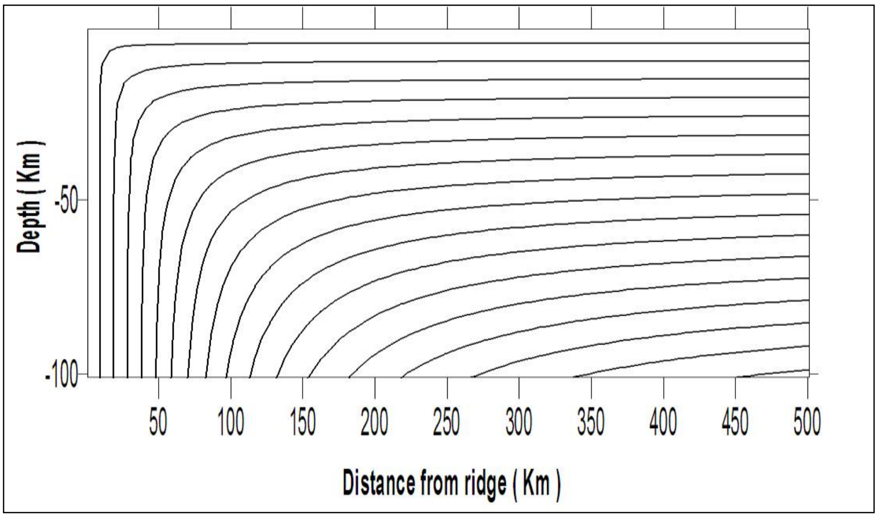
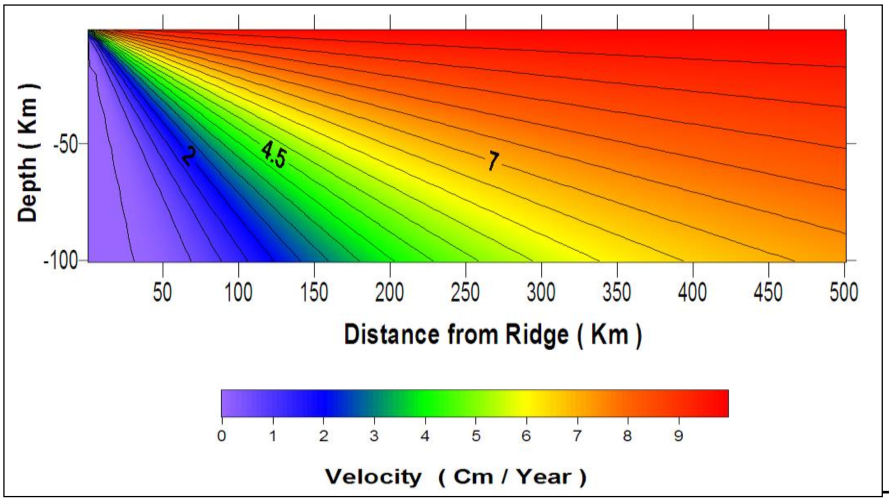


Fig. 8. The Particle movement path at Rifted Margin Predicted by Corner Flow Solution



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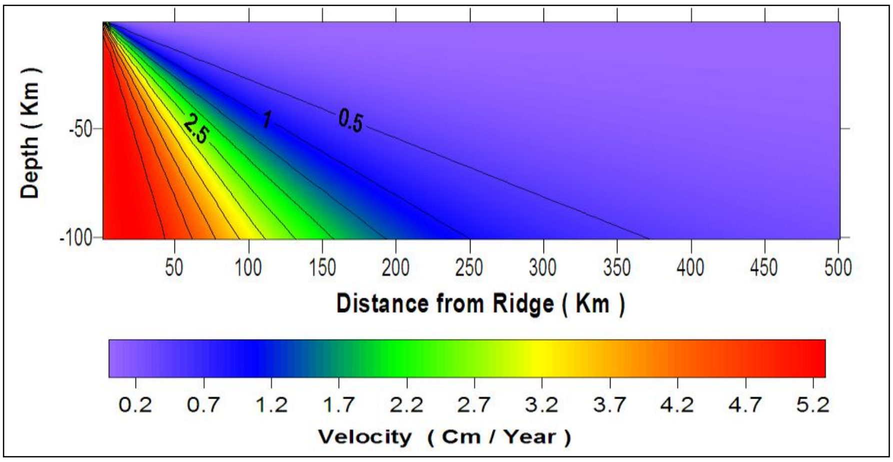

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Fig. 9. Value of Velocity (Cm/ Year) Predicted using Corner Flow Solution at Rifted Margin (A) Horizontal (B) Vertical, respectively

3. Discussion and Conclusion :

During rifting, extensional processes produce attenuation of the lithosphere and elevation of the thermal gradient, the thinning of the lithosphere is compensated by passive upwelling of hot material from the asthenosphere. As result the lithosphere becomes gravitationally unstable with respect to the hot asthenosphere beneath. The uplift of mantel rocks is related to lithospheric thinning, and ridge can be considered as a tectonic window on subcontinental mantle.

There are three arguments of thought on the nature and origin of the curst of pass margins located across the North Atlantic can be summarized in the following.

1. It is thinned and intruded continental crust
2. It is neither oceanic nor continental crust but consists of upper mantel rock exhumed by simple shear or by pure shear
3. It is oceanic crust formed at an ultra slow seafloor spreading rate

The manner of geodynamic modeling is being increaslly used to support our understanding of the formation of rifted continental margins, and the processing which should have been used over complex structure areas interesting, and more useful for modeling to establish and portray to define processing parameters can be tested against observation and provide the basis for design of new experiments, most significant behind the development of many geodynamic modeling is also need to understand the formation, thermal history, and subsidence of sedimentary basins. Corner flow technique use to predict the thermal structure of spreading center and subduction zones. In order to investigate the influence into the origin of the fluid flow field at mid-ocean ridge spreading center. Since the launching of the space age to determination of the global gravity field has been seen as major task. It's characterized by combination of satellite geodetic and gravity methods. Its result significantly improved measurement, and will aid the determination of global gravity field with constraint accuracy and higher resolution in geophysical research. It's currently recognized by several major oil companies as a new important prospecting tool for cost-effective mapping of the marine gravity field.

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