Geoscience Frontiers 4 (2013) 185–194

Contents lists available at SciVerse ScienceDirect

China University of Geosciences (Beijing)

Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf

Research paper

# Speculations on the mechanisms for the formation and breakup of supercontinents

J. Brendan Murphy[a,*], R. Damian Nance[b]

[a] Department of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia B2G 2W5, Canada
[b] Department of Geological Sciences, Ohio University, Athens, OH 45701, USA

ARTICLE INFO

*Article history:*
Received 17 May 2012
Received in revised form
9 July 2012
Accepted 18 July 2012
Available online 21 August 2012

*Keywords:*
Supercontinent cycle
Introversion
Extroversion
Pangea
Rodinia
Pannotia

ABSTRACT

The supercontinent cycle has had a profound effect on the Earth's evolution since the Late Archean but our understanding of the forces responsible for its operation remains elusive. Supercontinents appear to form by two end-member processes: extroversion, in which the oceanic lithosphere surrounding the supercontinent (exterior ocean) is preferentially subducted (e.g. Pannotia), and introversion in which the oceanic lithosphere formed between dispersing fragments of the previous supercontinent (interior ocean) is preferentially subducted (e.g. Pangea). Extroversion can be explained by "top–down" geodynamics, in which a supercontinent breaks up over a geoid high and amalgamates above a geoid low. Introversion, on the other hand, requires that the combined forces of slab-pull and ridge push (which operate in concert after supercontinent break-up) must be overcome in order to enable the previously dispersing continents to turn inward. Introversion may begin when subduction zones are initiated along boundaries between the interior and exterior oceans and become trapped within the interior ocean. We speculate that the reversal in continental motion required for introversion may be induced by slab avalanche events that trigger the rise of superplumes from the core-mantle boundary.

© 2012, China University of Geosciences (Beijing) and Peking University. Production and hosting by Elsevier B.V. All rights reserved.

## 1. Introduction

Our current understanding of the origin of supercontinents is rooted in hypotheses about the potential link between orogenesis and the episodicity in the generation and destruction of continental crust. This linkage was proposed before the general acceptance of plate tectonic principles and before the advent of precise U-Pb geochronology (e.g. Holmes, 1954; Gastil, 1960; Sutton, 1963; Armstrong, 1968, 1981), although the mechanisms responsible were unclear. Application of plate tectonic principles to pre-Mesozoic orogenic belts (Wilson, 1966; Dewey, 1969) linked crustal generation and destruction to processes occurring at constructive and destructive plate margins, respectively. Evidence for this episodicity strengthened as the number and the precision of radiometric dates increased during the 1970s leading to the hypothesis of a supercontinental cycle (Worsley et al., 1984, 1986; Nance et al., 1986, 1988; Fig. 1). This hypothesis proposed that the supercontinent Pangea, which formed in the Late Paleozoic and broke up in the Mesozoic (Cocks and Torsvik, 2002; Stampfli and Borel, 2002; Veevers, 2004), is only the youngest of a number of supercontinents that have formed, only to breakup and reform, since the Late Archean. Although not held universally (e.g. Stern, 2005; Hamilton, 2011), there is an emerging consensus that these "supercontinent cycles" have had a profound effect on the evolution of the Earth's systems for at least the last 2.5 Ga (e.g. Nance et al., 1986; Veevers, 1994; Hoffman et al., 1998; Condie, 2002; Knoll et al., 2004; Rogers and Santosh, 2004; Maruyama and Santosh, 2008; Meert and Lieberman, 2008).

However, an understanding of how supercontinents form is lacking. For example, Murphy and Nance (2003, 2005) pointed out that ancient supercontinents have formed by different mechanisms throughout geologic time. They proposed two *end member* mechanisms to account for these differences: (1) introversion (e.g. Nance et al., 1988), in which the oceanic lithosphere formed between dispersing fragments of the previous supercontinent (the interior ocean) is preferentially subducted to form the next

* Corresponding author.
*E-mail address:* bmurphy@stfx.ca (J.B. Murphy).

Peer-review under responsibility of China University of Geosciences (Beijing).

Production and hosting by Elsevier

1674-9871/$ – see front matter © 2012, China University of Geosciences (Beijing) and Peking University. Production and hosting by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gsf.2012.07.005

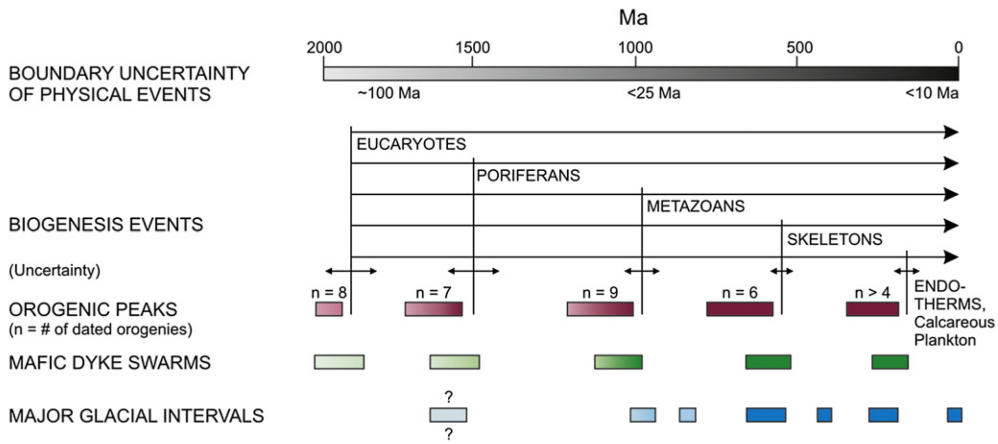


**Figure 1.** The supercontinent cycle of Worsley et al. (1984) summarizing episodic events in biogenesis (supercontinent breakup), collisional orogenesis (supercontinent amalgamation), mafic dike swarms (supercontinent rifting), and major glacial intervals (supercontinent stasis), the pattern of which suggested the existence of five supercontinents in the past 2 Ga.

supercontinent; and (2) extroversion (e.g. Hartnady, 1991; Hoffman, 1991), in which the ocean surrounding a supercontinent (exterior ocean) is preferentially subducted (Fig. 2). Paleogeographic reconstructions combined with Sm-Nd isotopic data from vestiges of oceanic lithosphere incorporated into orogenic belts imply that Pangea formed by preferential subduction of interior oceans (i.e. by introversion) during the Paleozoic, but that Pannotia formed by the preferential subduction of exterior oceans (i.e.

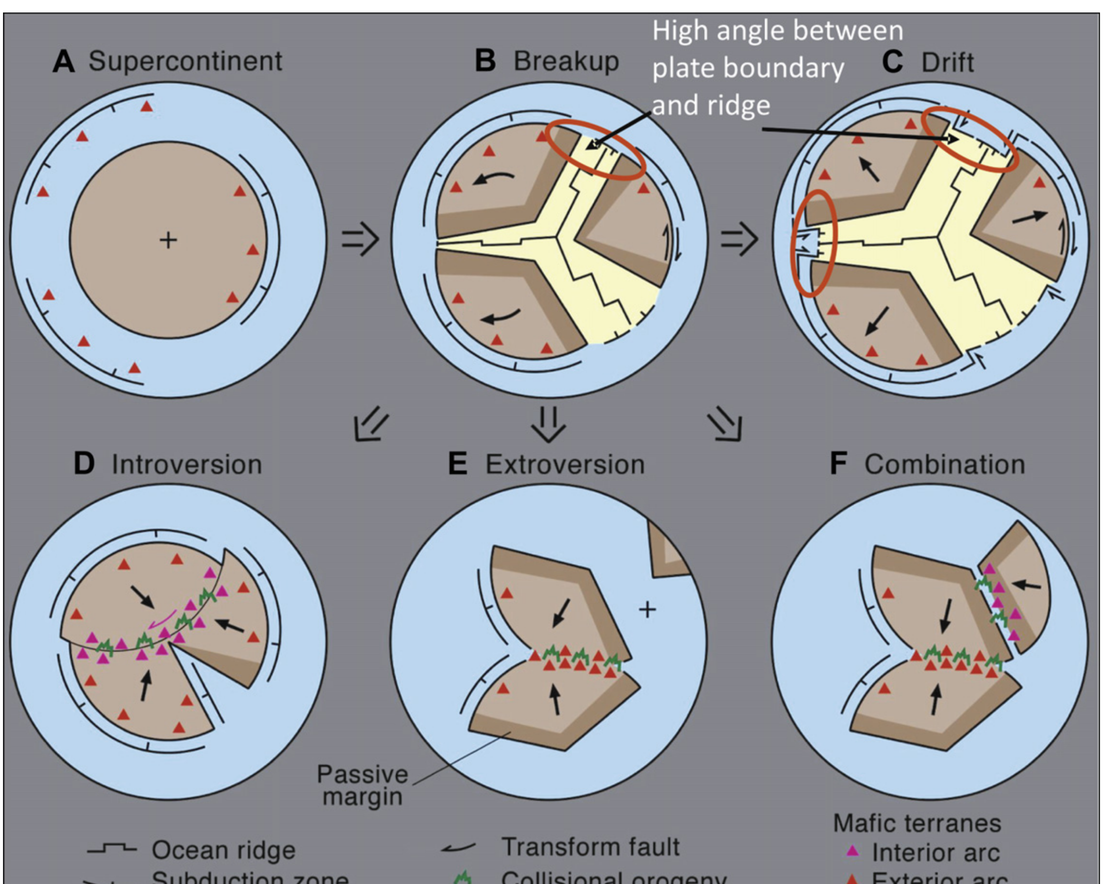


**Figure 2.** Schematic diagrams (modified from Murphy and Nance, 2003; Murphy et al., 2009) showing introversion and extroversion models for the development of a supercontinent. A–C show stages in supercontinent breakup, with relatively old oceanic lithosphere (blue) surrounding the supercontinent (exterior ocean), and the progressive development of relatively new oceanic lithosphere (yellow) between the dispersing continents (interior ocean). Note the high angle between the spreading ridges in the interior ocean and its plate boundaries with the exterior ocean. In B and C, subduction initiates along these boundaries (red ellipses). D: Configuration of a supercontinent formed by introversion (i.e. preferential subduction of the interior oceanic lithosphere). E: Configuration of a supercontinent formed by extroversion (i.e. preferential subduction of the exterior oceanic lithosphere). F: An intermediate case in which one ocean is closed by introversion and the other by extroversion. For orthoversion, see Fig. 1 of Mitchell et al. (2012).

Download English Version:

https://daneshyari.com/en/article/4681663

Download Persian Version:

https://daneshyari.com/article/4681663

Daneshyari.com