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Metacraton: Nature, genesis and behavior

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ABSTRACT

In this paper, we show with examples that cratons involved in intercontinental collisions in a lower plate position are often affected by orogenic events, leading to the transformation of their margins. In some cases, craton interiors can also be shaped by intense collisional processes, leading to the generation of intracratonic orogenic belts. We propose to call these events "metacratonization" and the resulting lithospheric tract "metacraton". Metacratons can appear similar to typical orogenic belts (i.e. active margin transformed by collisional processes) but are actually sharply different. Their main distinctive characteristics (not all are present in each metacraton) are: (1) absence of pre-collisional events; (2) absence of lithospheric thickening, high-pressure metamorphism being generated by subduction, leading to high gradient in strain and metamorphic intensity; (3) preservation of allochthonous pre-collisional oceanic terranes; (4) abundant post-collisional magmatism associated with shear zones but not with lithospheric thickening; (5) presence of high-temperature–low-pressure metamorphism associated with post-collisional magmatism; (6) intracontinental orogenic belts unrelated to subduction and oceanic basin closures. Reactivation of the rigid but fractured metacratonic lithosphere will cause doming, asthenospheric volcanism emplacement, and mineralizations due to repetitive mineral enrichments. This paper provides several geological cases exemplifying these different metacratonic features in Scandinavia, Sahara, Central Africa and elsewhere. A special focus is given to the Saharan Metacraton because it is where the term "metacraton" originated and it is a vastly expanded tract of continental crust (5,000,000 km^2). Metacratonization is a common process in the Earth's history. Considering the metacraton concept in geological studies is crucial for understanding the behavior of cratons and their partial destruction.

Contents

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1. Introduction

Cratons are defined as “part of the crust which has attained stability and which has not been deformed for a long time” (Bates and Jackson, 1980), thus they are Precambrian in age (Kusky et al., 2007). Such stability is attributed to the presence of a thick lithospheric mantle giving a high rigidity to cratons (Black and Liégeois, 1993 and references therein). However, cratons can be involved in continental collisions and be partly reactivated to generate continental tracts that are no longer cratons but that are not typical orogenic belts either. Such continental regions have been initially called “ghost craton” (Black and Liégeois, 1993) and were subsequently referred to as “metacraton” (Abdelsalam et al., 2002). A metacraton has been defined as “a craton that has been remobilized during an orogenic event but is still recognizable dominantly through its rheological, geochronological and isotopic characteristics” (Abdelsalam et al., 2002). “Meta” is a Greek prefix meaning “after” (in time or in space), but this prefix does not imply a direct temporal subsequence to the main event as the prefix “post” implies. For example, the term “post-collisional” refers to events that occurred shortly after collision. In contrast, metacratonic events can occur long after the craton was formed. “Meta” can also mean succession, change, or transformation. All these meanings are well-suited for describing the processes affecting cratons during continental collisions.

Abdelsalam et al. (2002) original definition of the term “metacraton” was strictly descriptive, and did not present explanations for the metacraton's genesis. Since the introduction of the term, several regional studies have applied the metacraton concept and brought important constraints for the understanding of metacratonic processes in NE Africa (Abdelsalam et al., 2003; Bailo et al., 2003; El-Sayed et al., 2007; Finger et al., 2008; Küster et al., 2008), in Hoggar (Acef et al., 2003; Liégeois et al., 2003; Bendaoud et al., 2008; Henry et al., 2009; Fezaa et al., 2010), in the Zambian Irumide (De Waele et al., 2006), in the Moroccan Anti-Atlas (Ennih and Liégeois, 2008), in Cameroon (Kwekam et al., 2010; Shang et al., 2010a), in Brazil (da Silva et al., 2005) and in China (Zhang et al., 2011a,b), in addition to numerous publications that have accepted the use of the term “Saharan Metacraton” to define this part of the continental crust in northern Africa.

It is thus of timely importance to properly define the concept of metacraton, discuss metacratonization processes, and present several examples to highlight the diversity existing within the common structure of metacraton and metacratonization. This is of paramount importance because the evolution of many metacratonic regions were often not understood because they are misinterpreted as only orogenic belts. Defining the nature, genesis and behavior of metacratons will enable the geoscientific community to recognize these important continental blocks and understand their tectonic characteristics; this is the aim of this paper.

2. Main characteristics of a metacraton

A craton is underlain by a thick, rigid and cold lithosphere. Events such as the initiation of subduction zones transform the craton's edges into active margins. Such events will lead to the loss of the craton's lithospheric rigidity and coldness, ultimately transforming the cratonic margins into orogenic belts in which old lithologies are mixed with juvenile ones. In this case, it is not easy to demonstrate that these old lithologies were part of a cratonic area and all cratonic characteristics will be lost. Metacratons, however even when they were formed through severely modifying tectonic processes, can still preserve major cratonic characteristics, especially rheological properties. Metacratonization can occur either at the margins of cratons or within their interiors (including the hinter parts of subduction-related margins), depending on the intensity of the metacratonization processes.

Due to the high level of force needed to destabilize rigid and thick cratonic lithosphere, it is most likely that metacratonization occurs dominantly during collisional or post-collisional events. Thus, this sequence of tectonic events can be used to establish several constraints on the metacratonic features abbreviated here as (mCf). These mCfs are outlined below and their significance in the evolution of metacratons will be demonstrated through several examples. It should be noted that it is not necessary for a given metacraton to display all mCfs to be qualified as a metacraton but that all metacratons must not bear features that contradict any of the mCfs.

2.1. mCf-1

A collision resulting from an oceanic basin closure involves by definition an active margin and a passive margin. In contrast to the active margin, the passive margin is not affected by major orogenic events before the collision. This description qualifies metacratons to be characterized by the absence of pre-collisional orogenic events.

2.2. mCf-2

During collision, the former passive margin, being located in the lower plate, will be subducted. Hence, in the case of a cratonic passive margin, a thick lithosphere is subducted. This results in a sharp increase of the pressure unrelated to lithospheric thickening of the cratonic plate but due to lithospheric plunge (continental subduction). Also, due to the thick nature of the subducted lithosphere, increase in temperature will be limited. The cratonic rigidity imposes a relatively static environment; hence high-pressure–low temperature (HP–LT) metamorphic paragenesis will develop only in regions where sufficient movements take place and are accompanied by fluids percolation, i.e. along shear zones of all scales. This makes metacratons to be characterized by syn-collisional HP–LT metamorphic conditions not linked to lithospheric thickening but locally developed along zones of high strain in selected lithologies preferentially accommodating this strain. Such strain and metamorphic localization allows for the preservation of original and undisturbed cratonic lithologies within regions of low-strain.

2.3. mCf-3

In a position of passive continental margin, cratonic margins can be accreted and overthrust by oceanic terranes (island arcs and ophiolites) that are preserved in this structural position because they are protected by the rigid cratonic lithosphere. Metacratonization can be associated with such early oceanic accretionary event, but it will generally be of limited extent. When this cratonic margin, which is covered by oceanic material, is involved in a later major