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EXPLORING CERAMIC RAW MATERIALS IN NIGERIA AND THEIR CONTRIBUTION TO NATION'S DEVELOPMENT

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ABSTRACT
Nigeria no doubt is an oil-rich nation and has solely relied on this resource as her economic main-stay to the utter neglect of all otter huge naturally endowed, mineral resources that abound almost everywhere in the country. This paper therefore attempts to explore the major ceramic raw materials particularly clay minerals in Nigeria, their locations and applications. Aggressive exploitation of these solid minerals will not only boost the nation's economy, but will enhance her technological development, changes the country's status from consumer to producer and create employment for the teeming unemployed youths. On a final analysis, embarking on this techno-economic journey will bring to focus the role and importance of ceramic education, hence adequate attention towards its development will be guaranteed.

KEYWORDS: *Oil-rich, clay minerals, ceramic raw materials, exploitation, ceramic education.*

I. INTRODUCTION

The term, "Ceramic" is derived from the Greek word "Keramos", meaning potter's earth or clay[1]. It has been applied traditionally to earthenware objects produced by the moulding and subsequentfiring of moist clay at low temperature to form hard, dense solids. Today, ceramics may be defined as inorganic and non metallic crystalline materials manufactured by heat treatment[2].In a broad sense, ceramics are defined as solid compounds that are formed by the application of heat and sometimes heat and pressure, comprising at least one metal and a non metallic elemental solid (NMES) or a non metal, a combination of at least TWO NMESs and a non metal[3]. For example, magnesia (MgO) is a ceramic since it is a solid compound composed of a metal, Mg bonded to a non metal, oxygen. Silica (SiO_2) is also a ceramic since it combines non metallic elemental solid, Si and a non metal, oxygen. It follows that oxides, nitrides, bonds, carbides and silisides of all metals and NMESs are ceramics. Ceramics are classified into two, viz; traditional ceramics and modern (advanced) ceramics. The traditional ceramics, called traditional because they have long been in use, have similar molecular structure to fired earthenware. Members of traditional ceramics include rocks, minerals, clay, concrete, refractories and porcelain. The modern ceramics which are becoming increasingly important in engineering and technology include pureoxide products (e.g. Al_2O_3, SiO_2, ZrO_2, ZnO, MgO, $MgAl_2O_4$), nuclear fuels, e.g. UO_2, Nitrides of Al, Si and B used as refractories and carbides of Si, B, W, Ti, etc used as abrasives and cutting tool materials.

II. GENERAL PROPERTIES AND APPLICATIONS OF CERAMICS

- Ceramic materials are hard and strong but brittle.
- They have good strength in compression due to the presence of ionic bonding and high melting temperatures but weak in shearing and tension.
- Ceramics are good electrical and thermal insulators due to the presence of porosity; often resistant to damage by high temperatures and chemical degradation or corrosive environments. Generally, they can withstand chemical erosion that occurs in other materials subjected to acidic/caustic environments and very high temperatures such as temperatures that range from 1000^0C – 1600^0C.
- They have low thermal shock resistance because of low thermal expansion coefficient and low thermal conductivity due to presence of porosity and defects.

The applications of ceramics to mankind cannot be overemphasized. Apart from serving the immediate needs of man, such as household utensils and decorative, it is being applied in technology in diverse ways which include:

- Grinding wheel/disc that puts the fine finish on ground steel shafting.
- Drilling bits (abrasives) used for drilling operations.
- Piezo electrical crystal that reads the pressure in an engine cylinder.
- Mico spacer in a vacuum radio tube.
- Titanium oxides in paints.
- Talc in baby powder
- Clay in refractories, porcelain and paper.
- Calcium carbonate in toothpaste.
- Ferrites in the memory of a large digital computer.
- Vehicle ceramic brake discs which are resistant to abrasion at high temperatures.

III. CERAMIC RAW MATERIALS IN NIGERIA

Clay is the longest known and most common of the ceramics. It has its origin in the mechanical and chemical disintegration of rocks. Clays are complex alumino-silicate compounds containing attached water.
Clay mineral is the most common and abundant mineral on earth; and it is located all over Nigeria. The industrial products obtainable from clays include pottery, refractories, chemical stoneware, electrical porcelain(insulators), bricks, tiles, Portland cement, filters, sanitary wares, drilling mud, sculptural ceramics and catalysts for the cracking of petroleum[1,5].The exploitation, processing and utilization of these clay minerals will positively influence the technological development and economic growth of Nigeria[6]. Tables 1 – 8 show the basic clay minerals (kaolin, feldspar, quatz, limestone, talc, silica sand, ball clay and bentonite) and their locations in Nigeria. In order to shun over-dependence in oil and imported goods, and diversify the economy, there is need for proper harnessing of these vast clay minerals. Hence, the suitability of the contribution of ceramics in the production of the aforementioned wares and tools will be guaranteed, thereby playing a key role in the economic and technological development of Nigeria.

Table 1: Locations of kaolin deposit in Nigeria

States	Locations
Abia	Umuahia South, Ikwuano, Isukwato, Nnochi
Akwa-Ibom	Ibiaku, Ntok Opko, Mbiafum, Ikot Ekwere
Anambra	Ozubulu, Ukpor, Ayamelum, Ekwusigo, Nnewi South, Ihiala, Njikoka, Aguata
Bauchi	Ackaleri, Genjuwa, Darazo, Misan, Kirfi, Dambam
Benue	Apa Ogbadibo, Okpokwu, Vandikya
Borno	Maiduguri, Biu, Dembua
Cross River	Alige, Betukwe, Mba, Behuabon
Delta	Aniocha South, Ndokwa East
Edo	All parts of the State
Ekiti	Isan-Ekiti, Ikere-Ekiti
Enugu	Uzo Uwani, Nsukka South, Udi, River-Oji, Enugu North
Imo	Ehime Mbano, Ahiazu Mbaise, Orlu, Ngor Okpalla, Okigwe, Oru
Kaduna	Kachia
Kano	Kano, Bichi, Tsanyawa, Dawakin-Tofa, Gwarzo Kankara, Dutsema, Safana, Batsari, Ingawa, Musawa, Malumfashi
Kebii	Danko, Zuru, Giro, Dakin-Gari
Kogi	Agbaja
Nasarawa	Awe, Keffi
Niger	Lavum Gbako, Bida, Kpaki, Patigi
Ogun	Ibeshe, Onibode
Ondo	Abusoro, Ewi, Odo-Aye, Omifun
Osun	Irewole, Ile-Ife, Ede, Odo-Otin, Ilesha
Oyo	Iwo, Alakia
Plateau	Barkin-Ladi, Mangu, Kanam
Yobe	Fika (Turmi)

Table 2:Locations of Feldspar Deposit in Nigeria

States	Locations
Adamawa	Maiba, Guyuk
Borno	Gwaza, Shani, Kwajaffa, Bakin Kasuwa
Edo	Etsako (East and Central)
Ekiti	Ijero-Ekiti
Katsina	Faskari, Batsari, Kurfi
Kebbi	Zuru, Yawuri, Kaoye
Kogi	Osara, Lokoja, Egbe, Okene
Nasarawa	Akwanga, Kokona, Nasarawa
Niger	Shiroro, Kontagora, Borgu
Ogun	Abeokuta
Osun	Oshogbo, Ilesha, Ede, Ipole, Iwo
Plateau	Bassa, Mangu, Panshin, Langtan North, Jos North & South
Taraba	Jalingo, Yorro, Baissa, Ussa.

Table 3:Locations of Limestone Deposit in Nigeria

States	Locations
Abia	Arochukwu, Ohafia, Bende
Anambra	Njikoka
Akwa-Ibom	Obotime
Adamwa	Guyuk, Shelleng, Ngurore, Numan
Benue	Ado, Apa, Gboko, Guma, Gwer West, Katsina-Ala, Konshisha, Makurdi, Oju, Okpokwu, Ushongo
Borno	Yadi-GIlan
Ebonyi	Abakaliki, Ikwo, Ishielu, Afikpo North, Ohaozara, Ohaukwu
Edo	Akoko-Edo, Owan East and West, Etsako East, Central and West
Enugu	Nkanu East, Agwu, Aninri
Gombe	Gombe, Yamaitu-Deba, Funa-Kaye, Numan
Imo	Okigwe
Kebbi	Jega
Kogi	Ajaokuta, Osara, Ekinrin-Adde, Itobe, Jakura
Nasarawa	Awe
Ogun	Ewekoro, Shagamu
Yobe	Garin Ari, Deda, Turmi (Fika), Kwayaya

Table 4:Locations of Quartz Deposit in Nigeria

States	Locations
Ebonyi	Ohaozara, Abakaliki
Ekiti	Idao, Iroko, Aiyegunle, Efon-Alaaye, Okemesi
Katsina	Faskari, Bakori, Kurfi, Funtna
Kebbi	Danko, Washgu
Plateau	Mansu, Panshin, Kanam, Langtang North

Table 5:Locations of Talc Deposit in Nigeria

States	Locations
Cross River	Obudu
Ekiti	Ijero-Ekiti
Kaduna	Zonkwa
Kogi	Isawu
Niger	Rafi, Shiroro
Osun	Ile-Ife, Illa, Ilesha
Oyo	Iseyin

Table 6:Locations of Silica Sand Deposit in Nigeria

States	Locations
Abia	Ukwa East, Aba North, Isiala-Ngwa North and South, Ukwa West.
Bayelsa	Sagbama, Southern Ijaw, Yenagoa
Benue	Buruku, Gboko, GUma, Katsina Ala, Vandeikya, Agato, Logo.
Borno	Dikwa, Gwoza, Maiduguri, Jere, Monguno, Kaga, Nganzai, Mobbar, Magumberi, Mafa, Kaga, Kukawa, Kalal Balge, Guzamala, Gubio.
Cross River	Ikom, Ibine Oban, Mfamosing, Okorotong Hills, Akamkpa, Obudu, Iwuo Ukem, Ibeno Beach, Mbo.
Delta	Ughelli North & South, ANiocha North & South, Bomadi, Burutu, Ethiope East & West, Ika South, Isoko North & South, Ndokwa East
Enugu	Enugu-Ikulu, Igbo Eze North & South, Isi-Uzo, Nkanu East, Uzo-Uwani
Gombe	Yamaitu-Deba, Akko, Dukku
Imo	Ihiagwa, Obinze, Isu, Njaba, Obowo
Kaduna	Kaduna
Kano	Dambatta, Makoda
Katsina	Zango, Baure
Lagos	Apapa, Badagry, Epe, Eti-Osa, Ibeju-Lekki, Ikeja, Ikorodu, Lagos Island, Ojo
Nasarawa	Lafia, Doma, Nasarawa
Niger	Gbako, Gurara, Lavun, Mokwa, Katcha, Muya, Wushishi, Bida
Ondo	Igbokoda, Atijere, Akata-Agbala, Zion Pepe, Aboto, Agerige, Ese-Odo, Ikare, Ilaje
Yobe	Ngeji (Fika), Damaturu, Jakusko, Karaguwa, Nguru, Tarmuwa, Geidam

Table 7:Locations of Ball Clay Deposit in Nigeria

States	Locations
Abia	Isukwuato, Ikwuano, Umuahia, Bende, Arochukwu
Akwa-Ibom	Nkari, Nlung, Ukim, Ikot-Etim, Eket-Uyo, Ekpere-Obom, Ikot-Okoro, Ikwa
Benue	Katsina Ala, Otukpo, Buruku, Gwer West, Markudi
Cross-River	Appiapumet, Ofumbongbaone, Ogurude, Ovonum
Delta	Ethiope East, Isoko South, Ndokwa East, South & West, Okpe, Sapele, Ughelli South, Warri North & South
Ebonyi	Ohaukwu, Ezza North, Abakaliki, Izzi, Afikpo South, Ohaozara
Enugu	Enugu, Isi-Uzo, Uzo-Uwani, Oji River, Udi
Ekiti	Ara-Ijero, Igbara, Ado, Orin
Kaduna	Kachia, Maraba-Rido, Farin-Kassa
Kano	All over the State
Kogi	All over the State
Niger	Lavun, Gbako, Suleja, Minna, Agaie, Paikoro, Bida, Murya, Mashegu
Ogun	Bamajo, Onibodo
Ondo	Erugu, Akoko, Ikale, Ode-Aye, Ute Arimogija, Ifon.
Plateau	Bassa, Barinkin-Ladi, Mangu, Kariam, Langtang North
Rivers	Etche, Ikwere

Table 8:Locations of Bentonite Clay Deposit in Nigeria

States	Locations
Abia	Arochukwu, Umuahia, Bende, Isukwuoto, Ikwuano
Adamawa	Mayo-Belwa, Guyuk, Mbi, Gombi
Akwa-Ibom	Itu
Anambra	Awka-South
Borno	Ngala, Marte, Mongunu, Gmboru, Dikwa
Cross River	Ogurude
Ebonyi	Ohaozara
Edo	Akoko-Edo, Owan East & West, Etsako East, Central and West
Gombe	Akko, Gombe, Yamatta, Debba
Yobe	Gujba

CLAY MINERALS IN NIGERIA: AN OVERVIEW

Kaolin

Kaolin is an industrial clay mineral with the chemical composition, $Al_2O_3.2SiO_2.2H_2O$. Due to its whiteness, fine particle size and plate-like structure, it holds importance as a major raw material in refractory applications and ceramic production[7]. Kaolin is also suitable as a coating, functional filler, extender, pigment, catalyst, concrete and fiber glass. Current applications of Kaolin include[7]:

- **Refractory Bricks:** Refractory bricks (fire bricks) are used to line high temperature furnaces and kilns, hence must be able to resist high temperature. User industries are all heat using industries such as iron and steel, ceramics, glass, cement, galvanizing and petroleum.

  Despite having huge deposits of kaolinite clay mineral in Nigeria, Nigeria continues to depend on external sources of refractory clays for its industries[8]. In 1987 alone, Nigeria imported about 27 million metric tons of refractory materials[9].

- **Ceramic Wares:** Kaolin stands out as the major raw material in almost all ceramic products. These include structural ceramics (drain pipes, sewage pipes, tiles, etc), white wares (household utensils, sanitary wares, etc), and porcelain, e.g. high and low tension electrical insulators and dental ceramics.

- **Paper Making:** The largest use of kaolin is in the production of paper where it serves both as a coating pigment and as a filler to replace fibre. Kaolin is suited in this aspect because it possesses desirable optical properties, chemically inert and relatively inexpensive when compared to other minerals.
- **Concrete:** Kaolin when added to concrete helps to improve strength and durability of concrete and motars. It reacts with free line during hydration to produce additional cementitious material, resulting in an improved high performance concrete.
- **Plastics and Rubber:** Kaolin is widely used as a functional filler in the plastic and rubber industry because of its inert chemical nature, unique size, shape and structure. Its presence results to improved overall performance of the plastics and rubber.
- **Paint:** In the production of paint, kaolin is used as an extender pigment. Primarily, kaolin in paint reduces the amount of expensive pigments e.g. titanium dioxide, assists the desired rheological properties that help maintain proper dispersion, and provides bulk to the product.
- **Pharmaceuticals and Cosmetics:** Kaolin is used in pharmaceuticals for treating different stomach irritations such as diarrhea. In cosmetics, it is used in various skin care products in removing black needs and dirt from the skin/skin pores[10].

  Kaolin is also eaten for health reasons and to suppress hunger, a practice known as geophagy. Its consumption is greater among women especially during pregnancy.

Feldspar

Feldspar is a rock forming mineral that is industrially important in glass and ceramic industries, and as a bonding agent in the manufacture of bonded abrasives e.g. wheels and discs of garnet, corundum, emery, etc. To some extent, feldspar is used as a filler and extender in paint, cements and concretes, fertilizer, insulating compositions, tarred roofing materials, used in medications like anticonstipation drugs and as a welding rod coating[11].

- **Feldspar in Glass Production:** About 70% of feldspar is used in the manufacture of glass products and 30% in ceramics and other products[12]. The raw materials for glass sand batch consists of silica sand, soda ash (Na_2CO_3) and limestone ($CaCO_3$) with feldspar making upto 10 – 15% of the batch.

  Alumina (Al_2O_3) from feldspar provides hardness, workability, strength, resistance to chemical corrosion and thermal shock resistance to the product. Alkali oxides (Na_2O and K_2O) from feldspar are fluxes. As fluxing agents, they reduce the melting temperature of the Silica sand in the batch, hence less energy is used, enabling the control of the glass viscosity and decreases the amount of soda ash needed[13,14].
- **Feldspar in Ceramic Production:** 30% of feldspar is used for manufacturing ceramics. Here, feldspar serves as a vitrifying (fluxing) agent forming a glassy phase at low temperatures, and also a source of alkalies and alumina in glazes[15].
- **Feldspar in Earth Sciences:** In earth sciences and archaeology, feldspars are used for dating, such as K-Ar dating, Ar-Ar dating, thermoluminuescence dating and optical dating.

Limestone

Limestone ($CaCO_3$) has numerous uses or applications, and these include:[16]

- Major raw material in the production of Portland cement.

- As an aggregate or base for roads and formulations, concrete and construction stone in buildings.
- It is used as a while pigment/filter or additive in products such as toothpaste, paints, papers and as a chemical feedstock.
- Limestone is used in the manufacturing and purification of molten glass.
- It is used in the manufacture and removal of impurities from molten iron.
- Limestone is used in the production of brake pads.

Talc

Talc is a silicate mineral, typically phyllosilicate composed of hydrated magnesium silicate with the chemical formular: $Mg_3Si_4O_{10}(OH)_2$. The most commonly known applications of talc include the following:[17]

- In cosmetics and dusting (antiperspirants), body and baby powders. The oleophilic (oil loving) nature of talc mineral helps to absorb natural oils, hence serving as a lubricant; while the slippery nature presents a pleasant feel.
- Paper Industry: Paper industry is the highest consumer of talc, and it is used as a filler to enhance opacity, brightness and whiteness of the paper. Talc also improves the paper's ability to absorb ink.
- Ceramic Industry: In this industry, talc mineral is used to prevent glaze crazing, lowers firing temperatures and reduces firing shrinkage of the ceramic products.
- **Paints and Coatings:** Here, talc is used as extender and filler. The platy shape of talc particles improves the suspension of solids in the container and helps the liquid paint adhere to the wall without sagging. It also improves exterior durability, controls viscosity, brushing and gloss properties.
- **Plastic Industry:** When used in plastics, the plates of talc make the plastic product more rigid and stronger, increases stiffness (and heat resistance), and reduction in shrinkage. For example, polypropylene parts reinforced with about 40% talc have replaced metal in many automotive applications such as bumpers.
- Talc minerals are also used as chewing gum dusting, insecticide carriers, rubber dusting, textile filling materials and as additive in asphalt roofing compounds.

Silica Sand

Silica minerals make up approximately 12% of the earth's crust and are second only to the feldspars in mineral abundance[18]. Free silica occurs in many crystalline forms viz; quartz, tridymite and cristobalite with quartz as the most commonly occurring form. Quartz, a crystalline form of silica is the only natural silica mineral used in significant quantities with millions of tones consumed annually by many industries. The basic applicators are:[18,19]

- **Construction Industry:** It is used as aggregate in concrete and mortar, building and road construction.
- **Glass:** Quartz silica is the major raw material in virtually all types of glass manufacture.
- **Ceramics:** Quartz sand has been ground to fine size as an ingredient of most clay bodies and as a major constituent of ceramic glazes. These typical ceramic products in high demand of silica include refractories, porcelain, tableware, sanitary ware, ornaments and tiles.
- **Foundry Casting:** It is used for the preparation of the form blends from cast iron, steels and non-ferrous foundries, and abrasive cleaning of casting surfaces.
- **Abrasives and Adhesives:** Quartz silica is used as sand paper, emery paper and in sand blasting for polishing and cutting glass, stone and metal. It is also used in manufacturing adhesives for tiles, natural rock pavement, marble, etc.
- Quartz is used as a hydrophobic (water-repelling) coatings, organic silicates and silicones, silicon carbides, silicon metal, smelting flux and alloying in metallurgy.

Ball Clay

Ball clay is a fine grained, high plastic sedimentary (secondary) clay which fires to a light or near white colour[20]. It exhibits highly variable compositions and consists of a mixture, primarily of kaolinite, mica and quartz with each contributing different properties to the clay. The inherent properties of ball clay is valued in its high plasticity, strength, light fired colour and bonding nature (binding agent). The high plasticity facilitates shaping and finishing of ceramic bodies, while the high strength allows green clay articles to keep their shape and withstand all types of moulding, shaping and conveying during manufacture[21]. Hence, ball clay adds plasticity to ceramic bodies inconjunction with kaolin (non-plastic clay) to produce a workable and malleable raw material.

Ball clay is highly recommended in the following applications:[22]

- **Sanitary Ware:** A ceramic body for sanitary ware typically consists of 30% ball clay to provide plasticity and workability, 70% kaoline, 30% feldspar and 20% quartz/silica.

- **Tableware:** Ceramic tableware utilizes ball clay to provide high plasticity and a good white fired colour, combined with kaolin, feldspar and quartz.
- **Wall and floor tiles:** Combined with talc, feldspar, quartz/silica and kaolin, ball clays are utilized to their plasticity and bonding properties.
- **Refractory clays:** An ability to resist the effects of extremely high temperatures makes ball clays ideal for use in refractory products such as dense and insulation bricks, and furniture bat.
- **Construction Ceramics:** Building materials such as bricks, clay pipes and roof tiles all contain ball clay.
- **Electrical Porcelain insulators:** Ball clays are found in the electrical porcelain components that provide insulation from high voltage currents.
- **Non-Ceramic Applications:** These include the construction industry, horticulture, agriculture and amenity industries used as fillers and extenders in polymers, adhesives, plastics, sealants, fertilizers and insecticides.

Bentonite

Bentonite is a plastic, colloidal, and absorbent aluminium phyllosilicate impure clay consisting mostly of montmorillonite. Industrially, two major types of bentonite exist, viz: sodium bentonite and calcium bentonite. The basic uses of bentonite are:[23,24,25]

- **Drilling muds:** It is used as a drilling fluid in the oil industry to lubricate and cool the cutting tools, remove cuttings and helps to prevent blow outs.
- **Binder:** Bentonite is widely used as a foundry-sand bond in iron and steel foundries, castings, and as a binding agent in the manufacture of iron ore pellets.
- **Clay bodies and ceramic glazes:** It is an important ingredient used to design clay bodies and ceramic glazes.
- **Bentonite clay is used in pyrotechnics to make end plugs and rock**-engine nozzle.
- **Purification:** It is used for decolorizing various minerals, vegetable and animal oils, clarifying of wines, liquors, ciders, beer, vinegar and the like.
- **Absorbent:** Bentonite is applied in pet care items, e.g. cat litter to absorb odour and surrounding faeces, absorption of oils and grease.
- **Ground water Barner:** It is used as sealant by providing self-seeding and low permeability barner; to line the base of land-fills; making slurry walls and for quarantining metal pollutants of ground water.
- **Medicinal:** Bentonite has been described as a bulk laxative, used as a base for many dermatologic formulas, and as a desiccant due to its high adsorption properties.

IV. RECOMMENDATIONS

The position of ceramic technology in Nigeria as a veritable tool in the development of any nation is that of neglect with attendant lack of manpower, moribund (in the case of previously established ceramic industries), in adequate funding and poor research patronage or grant occasioned with epileptic power supply and non-existence of statutory regulatory support[26]. This assertion is in agreement with the position of Dr. Chike Obidigbo who posits that:

"The prime sector of our economy, which is agriculture, exploitation of abundant mineral resources and local manufacturing is not been assisted by government and the preference of foreign products to that of made in Nigeria by the Nigerian populace is not helping matters either. Instead of government to support, she is rather frustrating the effort of the manufacturers and researchers with multiple taxation policy. Cost of production is too high coupled with the outrageous bank interest on loans. Power supply is massively construed in the hands of the politicians"[27].

For Nigeria to diversify her economic sources and improve her econo-technological growth, there is urgent need to maximally exploit the abundant clay minerals in the country. The exploitation and utilization process will yield the needed result through:

- Establishment and finding of ceramic technology and engineering department in our tertiary institutions.
- Establishment of effective ceramic industries and resuscitation of moribund ones.
- Improved power supply.
- Adequate funding of research and development (R&D), and manpower training in ceramic technology and engineering, and solid mineral exploitation and processing.
- Statutory policy to support local ceramic products.
- Imposition of high tariff on foreign ceramic products.

V. CONCLUSION

The abundant ceramic resources in Nigeria when exploited and utilized, will on the long term, result to economic empowerment, job creation and technological advancement.Transforming the challenges to opportunities will strengthen the nation and bring her close to the economically and technologically developed nations of the world.

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