

New Species of Bennettiales from the Jurassic Rocks of Sri Lanka

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Abstract- Plant fossil-bearing mudstones of Jurassic age are present in a small faulted basin within the Precambrian basement rocks at Tabbowa village, in the North Western province of Sri Lanka. The present study was conducted in the Tabbowa sedimentary beds and reports discovery of two new plant species that could probably be affiliated to *Otozamites* of Bennettiales group that prevailed in the Jurassic period. The reported fossils of this study are included under this plant group on the basis of leaf size, leaflet shape, and venation patterns, in the absence of diagnostic cuticle details. The discussed features are a comparison with those of Type Specimens of Bennettiales and the details found in the literature.

There are no previous records on these plant species from Sri Lanka or published reports elsewhere, the purpose of reporting the species is to document their systematic position in the plant world. Thus, the proposed names for new taxa are *Otozamites latiphyllus* Sri Lanka et.sp.nov.2012 and *Otozamites tabbowensis* Sri Lanka. et.sp.nov.2012. We consider that the proposed names of new taxa and descriptions expand the details of plant group of Jurassic Bennettiales facilitating advancement of scientific knowledge about this plant group.

Index Terms- Early Jurassic Plants, Tabbowa Sri Lanka, Bennettiales, *Otozamites*

I. INTRODUCTION

Almost all Jurassic (195-141 my ago) sedimentary rocks contain plant fossils some of which reveal the palaeo-environmental and climatic conditions under which the plants grew and evolved. Some comparable plant fossils are known to occur wide-spread and found in North America, South Africa, China, Russia, Australia, India, Antarctica and Madagascar; the fragments of *Gondwanaland* [10], though these lands are presently situated several thousand km apart from each other. Sri Lanka has also been a part of the *Gondwanaland*, though the Jurassic sedimentary rocks are of extremely limited occurrence, yet rich in a variety of plant fossils.

The genus *Otozamites* is an important component of fossil Bennettitalean plant during Mesozoic (225 - 65 my ago) Era [10]. This genus originated in the Late Triassic, thrived in the Early Jurassic and then decreased in diversity during middle and late Jurassic and finally became extinct in the late Cretaceous [15]. The biodiversity records and morphological patterns of foliage provide valuable information for understanding the evolution of plant species. Furthermore, it is helpful to reconstruct the palaeo-environment and palaeo-climate of Sri Lanka prevailed during the Mesozoic era.

The first description of Sri Lankan fossil *Otozamiets* was documented by [13] in 1942 from the Jurassic flora (Upper Gondwana) from Tabbowa area (Fig.1). Since then, no additional species have been identified from this area until the present study. During the present study seven species of *Otozamites* with different foliage types have been identified. Among these *Otozamites*, two are new to Sri Lanka and the present study identifies them to their species levels. The study mainly focuses on similar plant species by making observations on pinnule and their pattern of venation on world-wide literature.

II. OBJECTIVES

The objective of this paper is to present the evidence of new two plant fossils found in the Jurassic sedimentary rocks of Tabbowa, Sri Lanka and to document their systematic position in the plant world.

III. METHODOLOGY

Analysis of Sri Lankan Samples: The fossil plant materials collected in the study area (Fig.1) are mostly fragmentary and preserved as impressions in mudstone. Leaf damages prior to fossilization were also noted. Some samples however, are well preserved even with clearly visible venation patterns, though cuticles are rare.

Collected samples were studied under the microscope with reflected light. All specimens were photographed using light filters to enhance contrast using low angle lighting to reveal surface details. Sketches were made using CorelDraw graphics software. Fossil imprints were identified based on feature observations and comparing them with material available at the Natural History Museum of London, and the known examples given in the literature. Morphological terminology used by [8], [1] and [13] was used in the present study. All illustrated specimens are lodged in the Herbarium, National Botanical Department, Royal Botanical Garden, Peradeniya, Sri Lanka (PDA - type) and (GMU- holotype) - Museum, Department of Geology, university of Peradeniya for future reference. Specimens were numbered under “Tabbowa Mudstone Collection - **SL/TB/PDA/T-J/2013/Oto./1-2**” and **Holotype: SL/TB/GMU/T-J/2013/Oto.(holotypus)/1-17**

Abbreviations:

- | | | |
|--|------------------------------|---|
| SL - Sri Lanka | TB - Tabbowa, | PDA - Peradeniya National Botanical Department |
| T-J - Triassic - Jurassic | 2013 - Published year | Oto. - Plant name (Genus) |
| GMU - Geology Museum University of Peradeniya | | 1-7 - Collection No. |

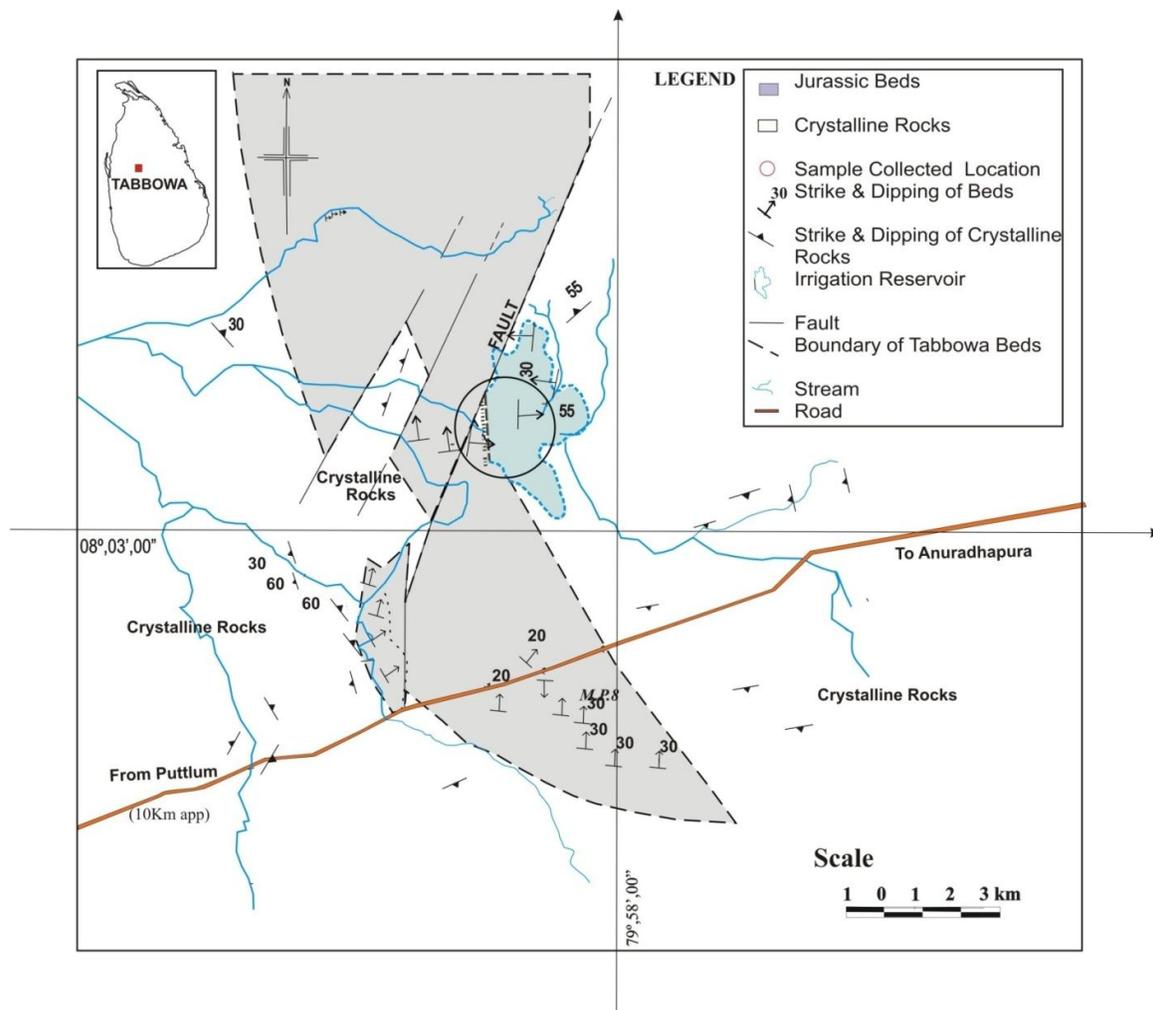


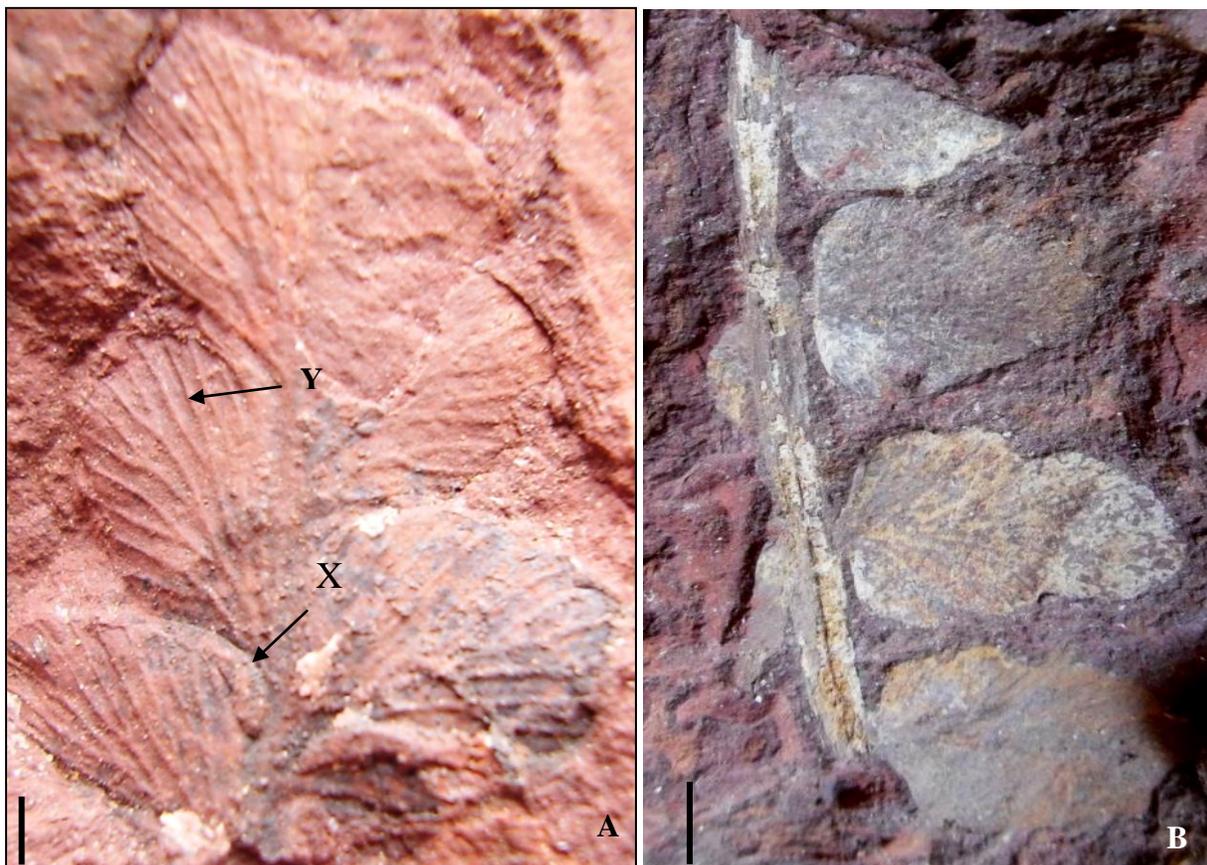
Figure 1. Location and the Geology of the Study Area. (Modified After Wayland 1925)

IV. GEOLOGICAL BACKGROUND

The Jurassic beds in Tabbowa, Sri Lanka (Fig. 1) are spread over an area of few tens of square kilometers forming a slightly elevated flat terrain. The beds are confined to a faulted basin within the Precambrian crystalline basement rocks, mainly granitic gneiss. The beds consist of a series of sandstone, feldspathic sandstone, siltstone and mudstone with occasional thin bands of nodular limestone.

The sediments vary in color from light gray, dark brown to purplish red while texture varying from fine to coarse grains. The rocks are well bedded, and jointed with variable strike and dips. This variation of the dips may be due to faulting within the basin and consequent tilting [12]. Evidence of faulting is clear in the gneissic rocks that surround the Tabbowa beds. Plant fossils are present only in the Mudstone and siltstone beds.

V. FINDINGS



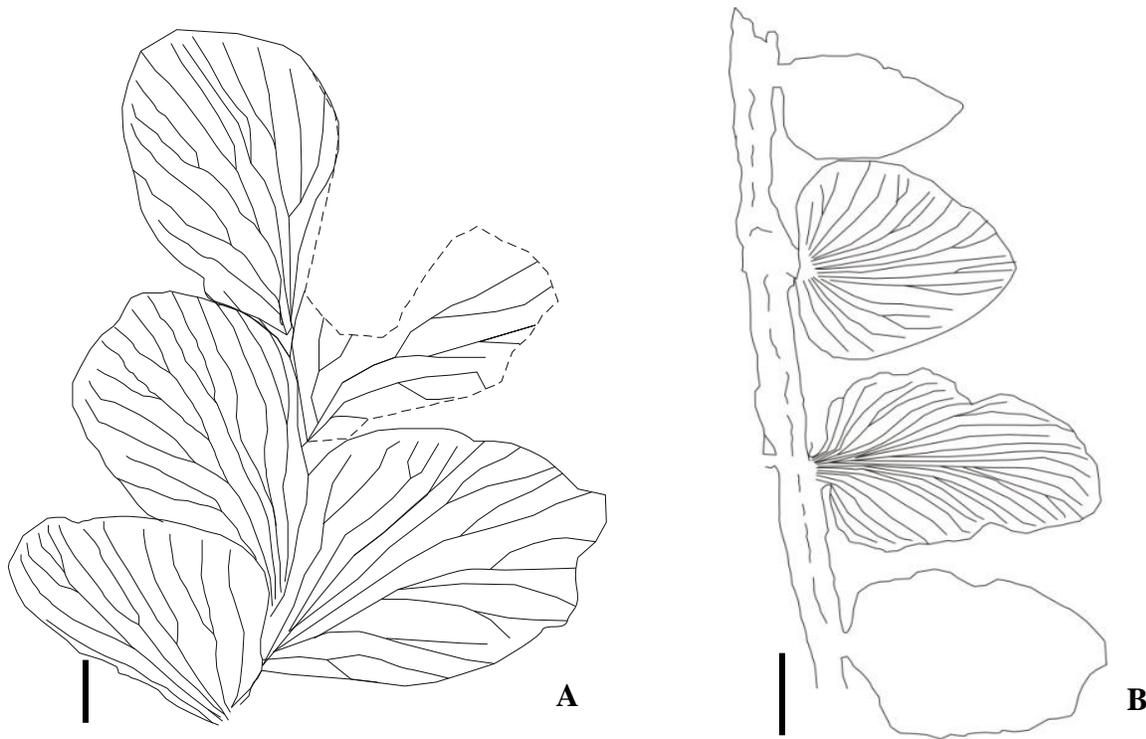


Figure 2 *Otozamites* sp from Tabbowa, Sri Lanka. (Scale Bar =5mm) Part of a leaf showing a bifurcate secondary veins (note arrow Y) and auriculate acroscopic basal margin (note arrow X) (A). Portion of apical region of a leaf (B). Line Drawings Depicting Specimens in Fig. 2. Showing the Variations of Pinnule.

Systematic Palaeobotany

Division : Cycadophyta
Order : Bennettitales
Genus : *Otozamites* Braun, 1843
Species : *Incertae Sedis*

Etymology : The species name compound of Latin adjective “lati-” meaning large and broad and Latin adjective “phyllus” meaning for leaf (latiphyllus – large or broad pinnule).

Sri Lanka : Species name refers to the locality :Sri lanka

Type species : *Otozamites latiphyllus* Sri Lanka Dharma *et* Geetha sp.nov. 2012 (Fig.2A)

Diagnosis – Rachis completely covered by pinnules. Pinnules alternate, thick, convex adaxially, arising at 35-40° · Pinnule margins reflexed. Acroscopic angle overlapping by diagonal basisopic angle of pinnule. Pinnule apex obtuse to rounded, Veins radiating from pinnule attachment, secondary veins forked, vein density high, Length/ width ratio; 1.3 -1.5:1

Preserved in : Ferruginous Mudstone deposited in a faulted basin of Crystalline basement rocks

Type Locality : Tabbowa sedimentary basin, Northwestern province, Sri Lanka

Repository : Herbarium, National Botanical Department, Royal Botanical Garden, Peradeniya, Sri Lanka (PDA - type) and (GMU- holotype) - Museum, Department of Geology, university of Peradeniya

Age : Early to Middle Jurassic

Otozamites latiphyllus Sri Lanka et.sp. nov.2012

Material Examined: 1 specimen as follows: Figure 2 A (17 specimens Examined)

Description: Fragment of a leaf about 15.0 mm wide (Fig. 2 A.), not complete. Three pairs of pinnules and one is damaged in apical region. The rachis is narrow; pinnules are partly concealed with acroscopic auricle base extending over the rachis (Fig.2 A - note arrow X). They are inserted at 35-40° angle to the upper side of rachis spirally or alternately by a short petiole. Pinnules are typically rounded to obovate, can be triangular or fan or rhombic shape, asymmetrical, serrated or dentate margin. The lamina is thin. Acroscopic margin is thick, convex and rounded to obovate- rhomboid. Pinnule base is acute and asymmetrical. Apex is rounded or obtusely rounded. Pinnules are closely spaced and slightly overlapping in the apical region. Average of pinnule length is 5.0 - 7.0 mm and the width is about 4.0-5.0 mm. Average length/ width ration is 1.2 -1.5 :1

Veins arise from a point at basiscopic margin at the pinnule base. They are distinct, dense, radiating from the point of pinnule attachment throughout the lamina, bifurcate regularly and continue to the pinnule margin. Secondary veins are dichotomized or forked once (Fig. 2A -note arrow Y) before they reach the margin. Cuticles are not preserved.

Order	: Bennettiales
Genus	: <i>Otozamites</i> Braun, 1843
Species	:Incertae Sedis

Etymology : Latin name for species refers to the locality :Tabbowa as *tabbowensis*
Type species : *Otozamites tabbowensis* Sri Lanka Dharma et Geetha sp.nov. 2012 (Fig.2B)

Diagnosis – well preserved incomplete single fragment of fossil frond with strong rachis, small triangular pinnule in apical region as rhombic or deltoid to ovate or lobed deltoid on basal region which are consist with short petiole. Alternate or opposite pinnule scars present on left side of the frond. Veins' radiating from pinnule attachment, vein density is high, dichotomized secondary veins are present.

Preserved in :Ferruginous Mudstone deposited in a faulted basin of Crystalline basement rocks
Type Locality : Tabbowa sedimentary basin, North-western province, Sri Lanka
Repository : Herbarium, National Botanical Department, Royal Botanical Garden, Peradeniya, Sri Lanka (PDA - type) and (GMU- holotype) - Museum, Department of Geology, university of Peradeniya
Age : Early to Middle Jurassic

Otozamites tabbowensis Sri Lanka et. sp.nov.2012

Material Examined: 1 specimen as follows: Figure 2 B

Description: Incomplete but well preserved frond with four pinnule along right side. Specimen is 40.0 mm long and 13.0mm wide. Petioles are short. Rachis is prominent and about 2.0 mm thick in basipetal region and about 1.0 mm thick in the acropetal region. Pinnule scars are visible on adaxial side of the rachis. Pinnules are laterally inserted to the rachis at an angle of 85° – 90°. Pinnule shape varies from ovate, lobed deltoid, to deltoid, rhombic from basal region to apical region. Pinnule base is flat and attached to short stalk or petiole. Base is symmetrical have acroscopic convex margin while basiscopic margin is slightly convex or auriculate. Apices are obtusely rounded. The size of the pinnule decreases from basal region to apical region. Overall length of mature pinnule is about 8.3mm while the breadth is about 4.5 mm. Veins are distinct, dense and arise from a point close to the basiscopic pinnule base. Veins radiate acropetally and basipetally throughout the lamina. Bifurcate veins continue to the pinnule margin, first basiscopic vein continuous to the rachis than the acroscopic vein. Pinnule length /width ratio ~ 2:1.

VI. DISCUSSION

Comparison of *Otozamites latiphyllus*: So far, there are four reported specimens which have rounded to obovate pinnule with reflexes, convex ,thick margin similar to *O.bunburyanus*, *O. tenuatus*, *O. boolensis*, *O. beanie* [14] [16] and [17]. Of these *O.latiphyllus* is similar to *O.bunburyanus*, veins initiate from a point close to the basiscopic side densely and radiating throughout the lamina,

bifurcating regularly, and persisting to the pinnule margin [4]. However, the size of the pinnule and the number of veins are much smaller in *O. latiphyllus*, *O. tenuatus* from Aslenian of Yorkshire is different by having an entire margin with smaller pinnule. *O. boolensis* from Jurassic of Australia and Antarctica sometimes has rounded to obovate pinnule [6].

The *O. latiphyllus* best resembles with *O. beanie* from Yorkshire Jurassic specimen which has large pinnule, dense and distinct radiating veins with serrate or dentate margins these are similar features to those of *O. beanie*. Therefore the specimen (Fig.2A) more closely resembles *O. beanie*. Absence of cuticles in Tabbowa specimens makes it difficult to place them under any of these species. Therefore, based on morphological characters, Tabbowa sample is named as a new species *Otozamites latiphyllus* Sri Lanka (Fig. 2A) with some reservations allowing for future investigations.

Also this species has been compared with fern family Osmundaceae, however, characteristic features of *O. latiphyllus* show great different with Osmundaceae key characters.

Key features of Osmundaceae :

Pinnule base: Pinnule are attached to the main rachis by their broad base and they are interconnected by thin sheath. In some of the species *Todites thomasii* [9] pinnule bases are contracted and interconnected but not as in *O. latiphyllus*.

Venation: Neuropteris or Cladophlebis type. Lateral veins are simple or forked once. But in some species lower most basal vein forks three times. Mid-vein is prominent and persist along the whole length of the pinnule [5].

Key feature to ascribe the present sample in Bennettitales and in Genus *Otozamites* : Secondary veins are un-forked in cycads. If secondary veins forked once, they are considered as Bennettitalean [5]. The present specimens can be ascribed to Genus *Otozamites*: on the basis of auricularly expanded acroscopic margin (X), forked secondary veins and continuous first basisopic vein to the rachis than the acroscopic vein [11]. Ascribe to species *O. latiphyllus* is having broad/large pinnule.

Comparison of *Otozamites tabbownensis*: Similar species of *O. bunburyanus* and *O. beanie* [17] and [16], have been reported from India and UK. *Otozamites bunburyanus* is a slightly larger pinnuled species compared to Indian and European species that are smaller pinnule named as *Otozamites beanie* [2].

O. bunburyanus veins initiate from a point close to the basisopic side densely and radiating acropetally and basipetally throughout the lamina, bifurcating regularly, and persisting to the pinnule margin [4]. The specimen (Fig. 2B) of *O. tabbownensis* though has more deltoid pinnule with short stalk or petiole compared to *O. bunburyanus*, has large sessile pinnule, dense and distinct radiating veins. Pinnule length/width ratio 1.5 - 2.3 :1 in *O. bunburyanus*. Since cuticles are the main feature that distinguishes between *O. bunburyanus* and *O. beanie* [15], absence of cuticles in Tabbowa specimens make it difficult to name them under any of these species. According to morphological characters however, *O. bunburyanus*, takes priority over *O. beanie*, for the Tabbowa sample (Fig. 2B) to name it as *Otozamites tabbownensis* Sri Lanka with some reservations.

Key Features of *O. tabbownensis* ascribed to Genus *Otozamites*: bifurcating secondary veins are radiating throughout the lamina and persisting to the pinnule margin, mid vein is not present. Pinnule bases are auriculate. Ascribed to species *tabbownensis* is having large deltoid, lobed deltoid pinnule with short-stalk or petiole, pinnule Length /width ratio ~2:1.

VII. CONCLUSIONS

The systematic attributions of the new taxa were discussed in all possible directions of frond of *Otozamites* of Bennettitales. The fossil flora discussed in this study, from Tabbowa sedimentary basin of Sri Lanka is unique and does not match with any other plant group characters that are described in the literature.

Present study shows that *Otozamites* of the Tabbowa rocks of Sri Lanka have a vast range of morphological variations among the species and also pinnules of the same species. The species *Otozamites latiphyllus* Sri Lanka Dharma et Geetha sp.nov. 2012 and *Otozamites tabbownensis* Sri Lanka Dharma et Geetha sp. nov. 2012 are new findings from this study and has not been reported before.

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