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Origins of Agriculture at Kuk Swamp in the Highlands of New Guinea

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ABSTRACT. Multidisciplinary investigations at Kuk Swamp in the Highlands of Papua New Guinea show that agriculture arose independently in New Guinea by at least 6950 to 6440 calibrated years before the present (cal yr B.P.). Plant exploitation and some cultivation occurred on the wetland margin at 10,220 to 9910 cal yr B.P. (phase 1), mounding cultivation began by 6950 to 6440 cal yr B.P. (phase 2), and ditched cultivation began by 4350 to 3980 cal yr B.P. (phase 3). Clearance of lower montane rainforests began in the early Holocene, with modification to grassland at 6950 to 6440 cal yr B.P. Taro (Colocasia esculenta) was utilized in the early Holocene, and bananas (Musa spp.) were intensively cultivated by at least 6950 to 6440 cal yr B.P.

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Contents of the paper

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1. Introduction

Investigation of agricultural origin in Papua New Guinea Highlands (Kuk) since 1966:

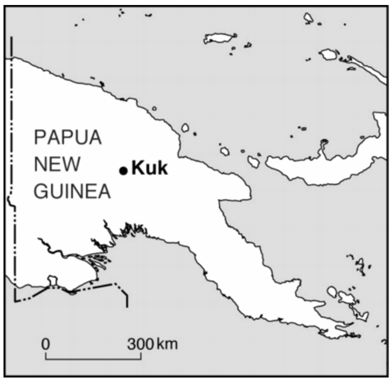
Golson (1977): archaeological remains of former cultivation dating 9000 BC.
Wilson (1985): association between *Musa* spp. phytoliths and archaeological phases.
Powell (1982): the presence of numerous edible plants throughout the Holocene (10000 y BP-).

⇔ No direct evidence that the archeological remains were anthropogenic nor *Musa* spps were domesticated ones.

★ Early independent agricultural development in New Guinea??

◆ Multidisciplinary data from renewed investigation at Kuk
→ independent aricultural development by at least 6950-6440 BP

2. Site and stratigraphy (複合層序学)



Kuk swamp in Papua New Guinea highlands, 1560m amsl, mean annual temp ～19℃, mean annual rainfall ～2700mm

Stratigraphy (Figure 2: A)

- Early to mid-Holocene: immature paleosol profiles;
→characteristics of periodically waterlogged environments.

3. <u>Paleoecological evidence</u>

● Previous studies: from 1750 y BP to 10000 y BP, open grassland between 1200-2000 m amsl were replaced by forest (dominated by *Nothofagus*：ナンキョクブナの仲間) due to climate warming, increased precipitation, and less frequent fires.

→ natural vegetation at 10000 BP (without anthropogenic disturbance): rainforests in dryland, swamp forest/grassland/sedge in wetland

● First signs of human impacts: change in forest composition, expansion of open herbaceous vegetation, increased concentration of charcoal in sediments

● Timing of the earliest anthropogenic impacts: 7800 BP in Baleim valley, 1700 BP in Tari basin.

◆ Sediment samples: 300 pollen grains and 200 phytoliths were counted in each sample. Obtained radio carbon date.

Figure 3:

(1) Before 10000 y BP: mosaic of forest and grassland.
(2) 10200-7400 y BP: grassland and fern flora increased; forest decreased.
(3) 10200-7400 y BP: periodical increase of charcoal density
(4) 10200-7400 y BP: dominant composition: *Nothofagus, Castanopsis*, and gymnosperms（裸子植物）→ *Pandanus,* Zingiberaceae, and Musaceae sect. Eumusa
(5) 6950-6440 y BP: forest declined as burning increased
(6) 6950-6440 y BP: Musaceae phytoliths ↑15% of total counts: banana growing in open grassland environment.

4. <u>Archaeological evidence</u>

Table 1: Three phases that are relevant to the origins of agriculture in New Guinea, because they predate known Southeast Asian influence on New Guinea at ～3500 y BP.

Table 1. Chronology for archaeological phases 1, 2, and 3 at Kuk Swamp (see tables S1 and S2 for dates and calibrations).

Phase	Golson 1977 (*4*) (uncal yr B.P.)	Subphase	Wetland remains	New dates (cal yr B.P.)
1	~9000	None	Amorphous palaeosurface	10,220 to 9910
2	6000 to 5500	None	Subcircular paleosurfaces	6950 to 6440
3	4000 to 2500	Earliest	Sinuous runnel	4840 to 4440
		Early	Rectilinear ditch networks	4350 to 3980
		Mid-late	Rectilinear ditch networks	None
		Late	Rectilinear ditch networks	Pre–3260 to 2800

<Phase 1> The oldest archaeological features at wetland margin at 10220-9910 y BP (**Fi 2: B**):

→ pits, stakeholes, postholes, and runnels
→ planting, digging and tethering of plants and localized drainage?
→ Single period of shifting cultivation ?

<Phase 2> Regularly disturbed mounds at 6950-6440 y BP (**FI 2: C**):

→ Regular morphologies of features, numerous stakeholes and postholes, elevated charcoal
→ mound cultivation?

<Phase 3> Drainage and ditch at 4350-3980 y BP (**FI 2: D**):

→ intensified agriculture in wetland environment?

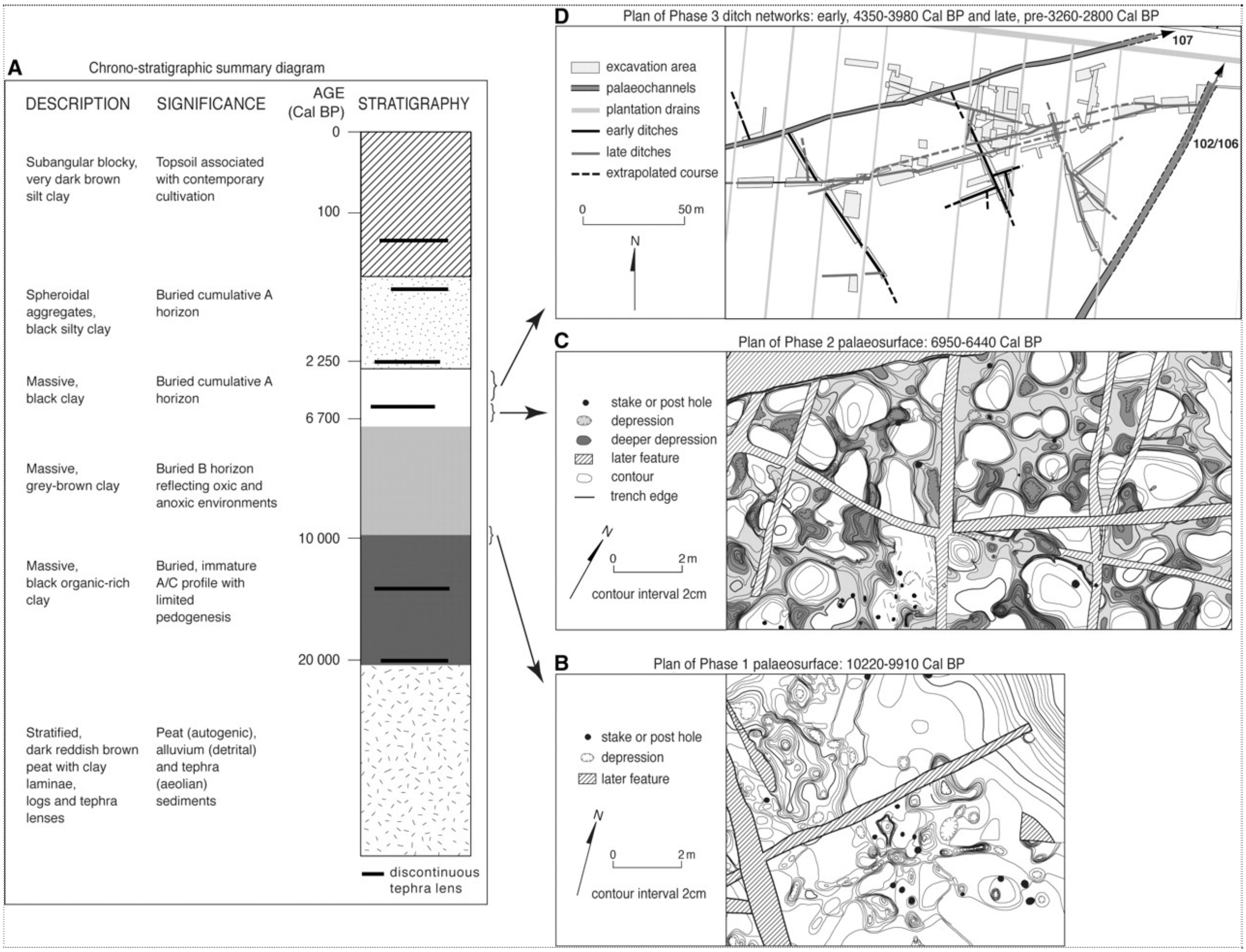


Fig. 2. Archaeostratigraphic representation of phases 1, 2, and 3.

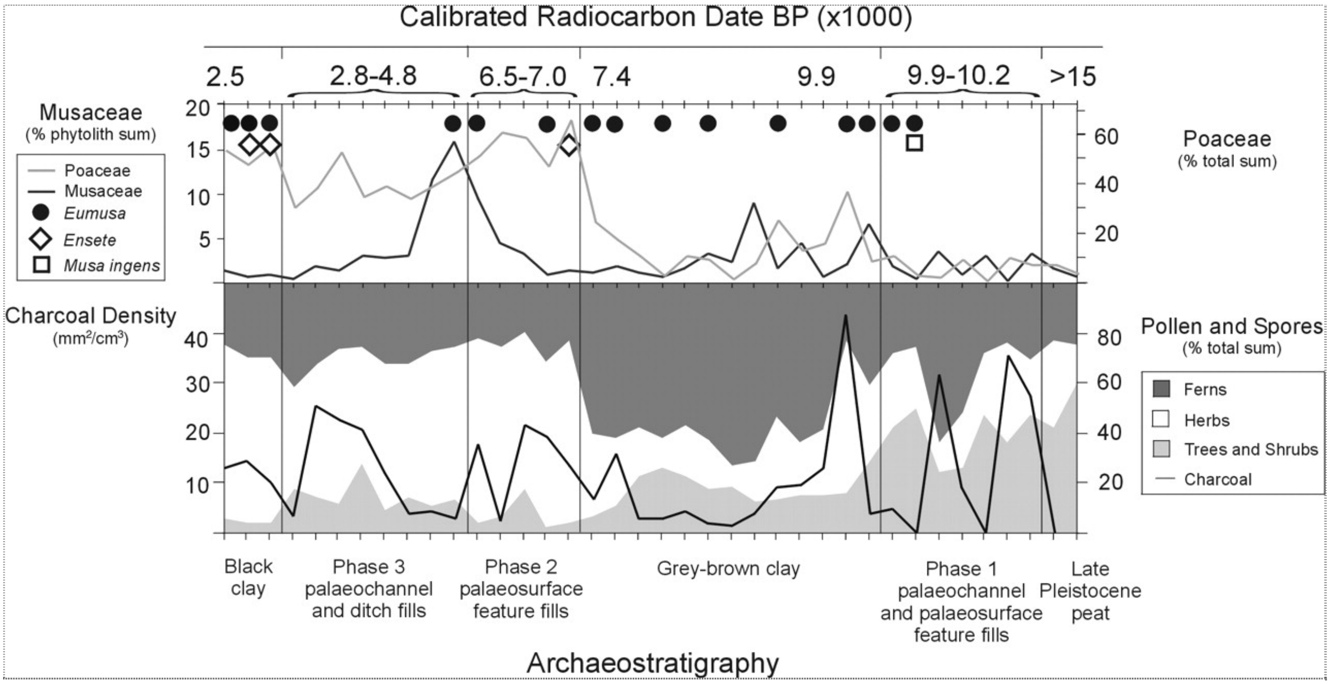


Fig. 3. Selected pollen and phytolith data from the Kuk Swamp samples (n = 38). Ages are based on radiocarbon dating of stratigraphic features associated with phases 1, 2, and 3 and intervening stratigraphy (that is, gray clay). Samples are arranged in order of oldest (sample 1, right-hand side of the diagram) to youngest (sample 38, left-hand side). The lower half of the diagram depicts pollen and spore summary curves (for ferns, herbs, and trees and shrubs) and charcoal density (as area of pollen slide). The upper half of the diagram shows Poaceae (as percentage of total sum of pollen and spores) and Musaceae phytoliths (as percentage of total phytolith sum), with the presence of diagnostic seed phytoliths assigned to Eumusa, *Ensete* sp., and *Musa ingens* depicted as symbols.

5. Archaeobotanical evidence

(1) Numerous edible plants were present in Kuk before 10000 y BP.
(2) No association with plant remains and archaeological features → plants may not be domesticated
(3) Disturbance in wetland margin may have been intended to increase the availability of edible-useful plants → the plants are still utilized today.

(4) Microfossils from taro (*Colocasia esculenta*) and banana (*Musa* spp.) may have been presented in PHASE 1.
(5) Starch grains from taro are present on the worked edges of three stone tools from Phase 1 and phase 2, and intervening gray clay.
(6) Taro (*Colocasia esculenta*) was also found in a Pleistocene site in Island Melanesia and an early Holocene site in lowland New Guinea.
(7) Because Taro is a lowland crop, Highland taro may be a product of anthropogenic selection.

(8) Musaceae phytoliths are present from 10000 y BP until present **(Fig 3)**.
(9) Musaceae phytolith found in high percentage before 6950 y BP → only suggestive of deliberate planting (because banana may exist in wooded or edged environment in nature)
(10) Musaceae phytolith were also found in Phase 2 and phase 3 (when grasslands dominated) → deliberate planting → because (a) Musa banana do not produce large amount of phytolith, (b) *Musa* banana may not survive when burned (*Ensete* may survive, but found only marginally) → Musa banana may have been planted deliberately
(11) Phytoliths of Australimusa banana （フェイバナナ）was not found.
(12) Eumusa cultivars may have been domesticated in PNG highlands (cf. Lebot V,1999).

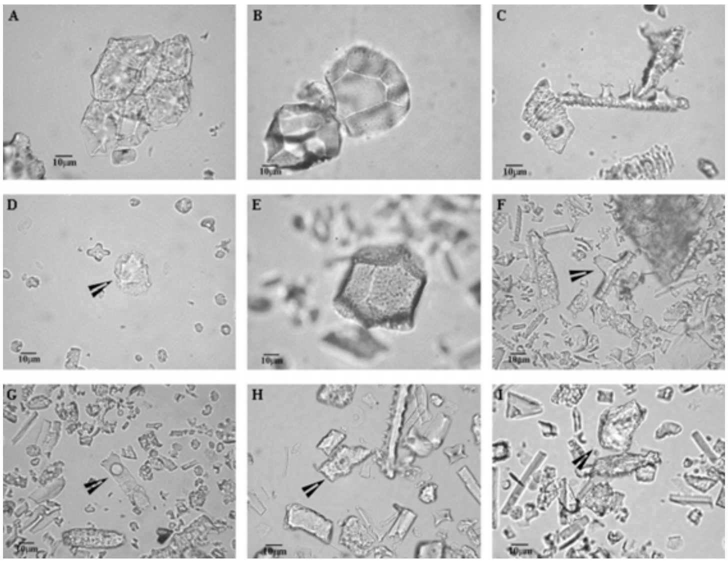


Fig. 4. Photographs illustrating discrimination of contemporary and prehistoric *Musa* spp. phytoliths. (**A**) Articulated phytoliths from seed of *Musa acuminata* ssp. *banksii* showing distinct dorsal ridging of Eumusa seed phytoliths (modern reference: sample QH067962). (**B**) Seed phytolith from seed of *Musa ingens* (modern reference sample). (**C**) Dorsal and lateral views of *Ensete glaucum* seed phytoliths (modern reference: sample QH356652). (**D**) Fossil Eumusa seed phytolith with distinct dorsal ridging found in the phytolith assemblage from the base of a phase 2 feature fill (sample 5). (**E**) Faceted phytolith morphotype found in the phytolith assemblage from the upper fill of the phase 1 paleochannel (sample 19). It is similar to the seed morphotype of *Musa ingens*, although its surface is more heavily textured. (**F**) Lateral view of *Ensete* seed morphotype found in a phase 2 feature fill and the clayey black sediment above (samples 3 and 4). (**G**) Articulated chain of *Musa* leaf phytoliths from within the gray clay sequence between phase 1 and phase 2 (sample 10). (**H**) Fossil leaf phytolith of *Musa acuminata* from the upper fill of the phase 1 paleochannel (sample 19). (**I**) Fossil Eumusa seed phytolith from the upper fill of the phase 1 paleochannel (sample 19).

6. Conclusion

(1) Gradual emergence of agriculture (shifting-cultivation) in Highlands of New Guinea is suggested by (1) cumulative forest disturbance, (2) archaeological remains of cultivation on the wetland margin, (3) the use of *Colocasia* taro, (4) presence of Eumusa bananas.
(2) By 6950-6440 y BP, mounding, creation/maintenance of anthropogenic grasslands, deliberate planting of banana started. Eumusa cultivars were domesticated.
(3) New Guinea is a primary center of agricultural development and plant domestication. Eumusa bananas and Colocasia taro may have been domesticated in New Guinea.
(4) Independent agriculture is not necessarily a trigger of large-scale demic expansion, social stratification, and the rise of “civilization”, which challenge the conventional interpretation of prehistorical social change.

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Enhanced: New Guinea: A Cradle of Agriculture

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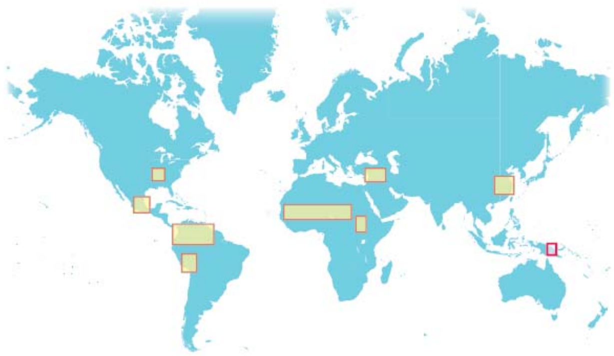
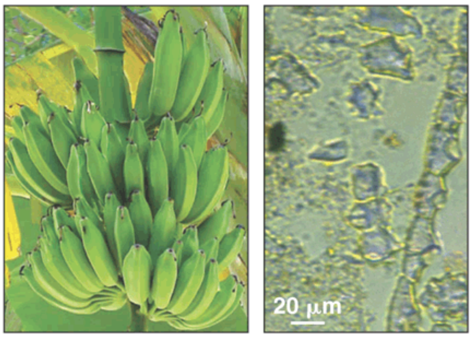


Centers of agricultural origins. New Guinea is marked in red.



New Guinean agricultural heritage: the banana. (**Left**) Modern banana. (**Right**) Modern banana phytoliths, similar to those that indicate its cultivation in New Guinea 7000 years ago.

＜参考＞　バナナについて　http://www.geocities.jp/banana_rnj/aboutbanana.html より一部を転載

1. バナナの分類と名称の由来

バナナ(Musa spp.)は植物学的にいえば、単子葉類ショウガ目バショウ科バショウ属の多年生草本です。ショウガ目はバショウ科の他、ショウガやウコン、カルダモンが含まれるショウガ科、極楽鳥花が知られるストレリチア科など、8 科に分類されています（分類によっては 6 科）。バショウ科にはバショウ属(Musa Genus)とエンセーテ属(Ensete Genus)の 2 属があります。栽培種のエンセーテ(Ensete ventricosum)は、かつてアビシニア・バナナと呼ばれていたように、エチオピア南部で重要な作物で、果実ではなく偽茎や塊茎に含まれるでんぷんを食用とします。

さらにバショウ属は 5 つの節(section)に分類されます。すべての栽培バナナは、耐冷性が高く日本でも栽植されるバショウと同じく、Eumusa 節に含まれます。南太平洋におもに分布するフェイ・バナナや、フィリピンのマニラ麻の原料で知られるアバカは、Australimusa 節に属します。Callimusa 節と Rhodochlamys 節には観賞用に利用される種がありますが、食用にはなりません。これら 4 節は染色体数が x=10～11 で、Eumusa 節は x=11 です。ただし、草高が 15m にも及び、世界でもっとも大きい草本とされる Musa Ingens（Ingentimusa 節、1 節 1 種でパプア・ニューギニアに分布）だけは例外的に x=14 になります。エンセーテ属は x=9 です。

Eumusa 節のなかで人類にもっとも重要な役割を果たした種が、ムサ・アクミナータ(Musa acuminata)とムサ・バルビシアーナ(Musa balbisiana)という 2 つの野生種です。アクミナータの野生種は AA、バルビシアーナの野生種は BB という 2 倍体の遺伝子型（ゲノムタイプ）をそれぞれ有しています。これらの野生種は多数の堅い子実を果実に含むため食用にはなりません。しかしながら今日世界で栽培されるバナナはすべて、これら 2 種に由来した同質倍数体、もしくは交雑倍数体の遺伝子型になります。野生のアクミナータは他家受粉で通常は結実しますが、単為結果性を獲得したことによって、受精の有無に関わらず果実が生長できるようになりました。これが栽培種のアクミナータ(AA)の始まりです。さらに雌性不稔や 3 倍体(AAA)の選抜によってさまざまな品種が創出されていきました。3 倍体のバナナに種子が含まれることはごくまれですが、2 倍体の品種には種子が含まれていることが時おりあります。AA や AAA の品種が栽培されるようになり、それらが野生バルビシアーナ(BB)の自生地に到達したことで、初めて両者の交雑が可能になったと考えられます。交雑は栽培品種間でもおこなわれる可能性があります。長い歴史のなかで時おりの自然交雑と、突然変異とがバナナの多様性を生みだしていったのでしょう。

いまでは栽培バナナの多くが 3 倍体の品種になっています。例えば、キャベンディッシュ(Cavendish)やグロ・ミシェル(グロス・ミッチェル、Gros Michel)に代表される輸出用バナナは、ほぼすべてがアクミナータ同質 3 倍体(AAA)の品種で、デザート用に利用されます。この他に AA（アクミナータ同質 2 倍体）、AB（交雑 2 倍体）、AAB、ABB（いずれも交雑 3 倍体）といった遺伝子型のバナナが熱帯各地で栽培されており、フィリピンなどではわずかながら BB や BBB といったバルビシアーナ（同質 2 倍体または 3 倍体）の栽培品種も存在しています。

2.バナナの歴史

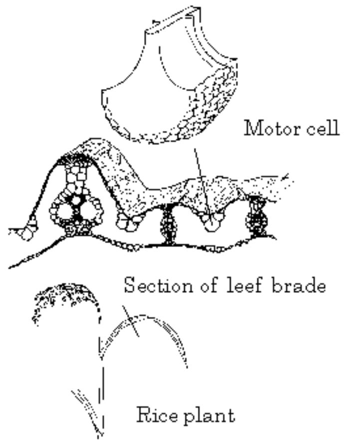
バナナはそもそもマレー半島を中心とした東南アジアの湿潤地帯で栽培化されたと考えられています。今日でもこの一帯の森林部に野生種のムサ・アクミナータが幾種類も分布しています。インドネシアだけで 15 の変種があると報告されています。一方、フィリピンやインド北部には、別の野生種群ムサ・バルビシアーナが見られます。これらの分布が、東南アジアからインドにかけての地域をバナナの起源地と考える根拠となっています。またパプア・ニューギニアにおけるバショウ属の種の多様さから、この島が起源の 1 つと考える説もあります。

栽培化されたバナナは、紀元初期にポリネシア人によって太平洋の島嶼部へもたらされました。アフリカへのバナナの伝播経路については諸説ありますが、それは、紀元前 1000 年頃の東アフリカ地域へのプランテンの到来、アクミナータ系バナナの到来、それ以後のその他のバナナの到来、紀元 1500 年前後のポルトガル人による西アフリカ地域へのバナナの導入まで、継続的、重層的なものであったと推定されます。アフリカに到来したバナナは、体細胞突然変異と農民による意図的、非意図的な人為選択を介して品種レベルで多様化し、その栽培と伝播における人間との密接な相互交渉を通じて、東アフリカ、中部アフリカ、西アフリカに独自のバナナ栽培文化が生みだされていきました。

<What is phytoliths?>

Paleoenvironmental reconstruction is an important contribution of phytolith analysis (the study of plant opal silica bodies) to archaeology and paleoecology.　Phytoliths extracted from natural soil accumulations provide a detailed record of vegetation, and the impact on that vegetation by human activities such as clearance for agriculture.
Successful tapping of the wealth of information from phytolith analysis for the study of past vegetation depends on two things: (1) establishing diagnostic types for key indicator species, and (2) developing phytolith vegetation analogs, or signatures, for modern plant communities.

(Source: University of Missouri's Paleoethnobotany Laboratory. http://www.missouri.edu/~phyto/flora1.htm)

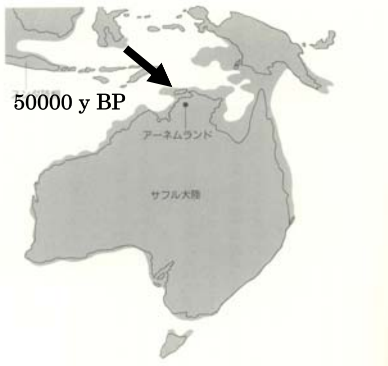


Motor cell silicabody of rice plant

(Oryza sativa L.)

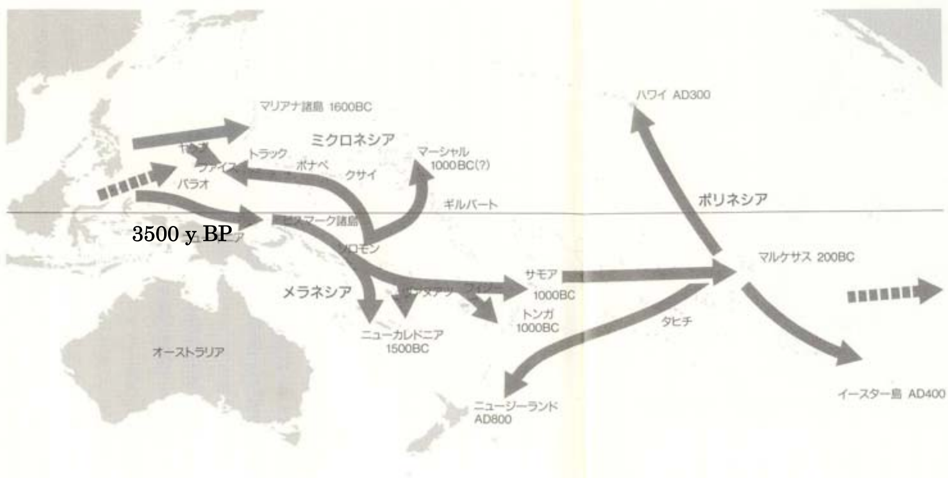
<Prehistoric colonization of South Pacific Islands>

First humans who crossed Wallace line to Sahel continent were the speakers of <u>non-Austronesian language group</u>. They probably arrived at current Arnemland at around 50000 y BP, then moved to interior Sahel and New Guinea.　Australian aborigine and majority of New Guinea people are the descendants of these settlers. As were in the other regions on the globe, they did not know agriculture at least before 10000 y BP.



約5万年前のサフル大陸とスンダ陸棚（実線は現在の海岸線）

The speakers of <u>Austronesian language group</u>, who originated from Southern China, later arrived at the northern coastal areas of New Guinea Island at around 3500 y BC. They may have brought domesticated crops or animals from Southeast Asia. The speakers of Austronesian language group further moved to remote Oceania.　Polynesian people and a part of Melanesia and Micronesia people are the descendants of these settlers.



オーストロネシア語を話す集団のオセアニアへの拡散ルート