The expansion of *Araucaria* forest in the southern Brazilian highlands during the last 4000 years and its implications for the development of the Taquara/Itararé Tradition

José Iriarte and Hermann Behling

An examination of the late Holocene environmental and cultural sequences of the southern Brazilian highlands indicates that the colonisation of this region by the Taquara/Itararé people is associated with the expansion of *Araucaria* forest resulting from the onset of wetter climatic conditions in the region, which started between around 1410 and 900 cal. yr BP. The more intense and permanent human occupation of this region is associated with the advance of *Araucaria* forest, which provided Taquara/Itararé groups with a newly abundant and reliable resource: *Araucaria* seeds. In addition, we review the evidence for landscape transformation associated with the beginning of food-production in the region. Charcoal records show that local populations may have practiced slash-and-burn agriculture at lower elevations since the beginning of the late Holocene around 4320 cal. yr BP, and continued this practice during the second part of the late Holocene.

Keywords: fossil pollen, Holocene, Brazil, climate change, Taquara/Itararé Tradition, Araucaria forest, human-environment interactions

Introduction

The archaeology of the late Holocene of the southern Brazilian highlands (hereafter SBHs) has received a new impetus in the last decade through the developments of several new archaeological projects (e.g., Beber 2005; Chmyz *et al.* 2003; De Masi 2005; Robrahn-González and DeBlasis 1998; Schmitz 2002). In parallel, new paleoecological work carried out in the region (Behling 1995; 1997a; 1997b; 2002; Behling and Pillar 2007; Behling *et al*. 2004; 2005; Bissa *et al*. 2000; Garcia *et al*. 2004; Iriarte 2006a; Ledru *et al*. 1998; Scheel-Ybert 2000; 2001) has substantially expanded and refined our understanding of the mid- and late-Holocene environments. In turn, improved environmental reconstructions have allowed archaeologists to explore human-environmental dynamics in more precise ways (Iriarte *et al*. 2004; Rodríguez 2005; Scheel-Ybert 2001; Schmitz 2001/2002). This paper reviews the existing archaeological data and correlates it with the paleoenvironmental evidence gathered for the region. The comparison indicates that the climatic fluctuations that took place during the mid and late Holocene had a major impact on the pre-Hispanic groups that inhabited the region. Ten pollen sequences from the Brazilian states of Rio Grande do Sul, Santa Catarina, and Paraná document the beginning of a more humid period starting around 4480-3780 cal. yr BP (4000–3500 ^{14}C yr BP), which became more intense between about 1410–900 cal. yr BP (1500–1000 ^{14}C yr BP) depending on the region. The archaeological data indicate that this pronounced late-Holocene environmental change is associated with a more intense occupation of the SBHs as evidenced by the development of the ceramic Taquara/Itararé Tradition. The proliferation of Taquara/Itararé pithouse villages appears to be related to the exploitation of a newly available,

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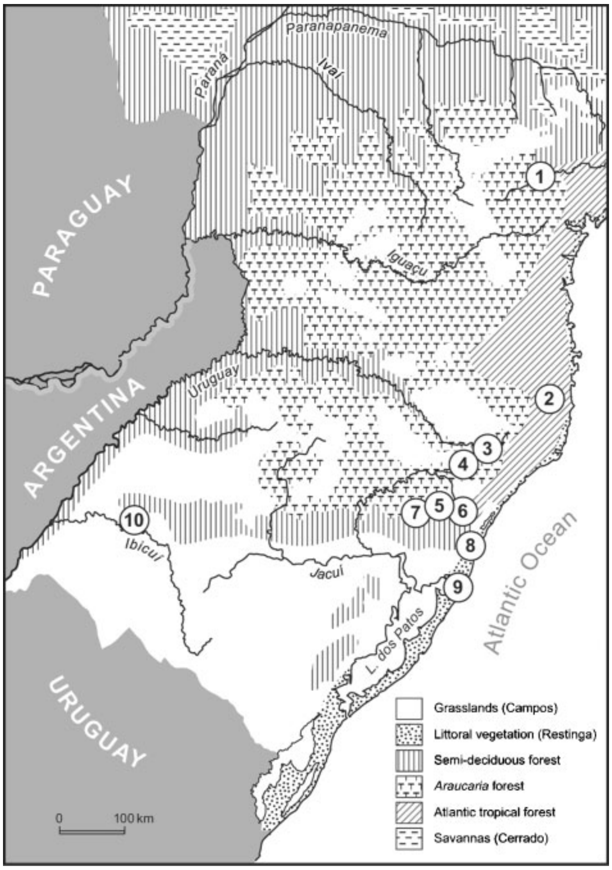

Figure 1 Southern Brazilian highlands and its major vegetation types showing pollen sites discussed in the text (modified from IBGE 1977). Key: 1. Serra Campos Gerais; 2. Serra da Boa Vista; 3. Morro da Igreja; 4. Serra do Rio Rastro; 5. Aparados da Serra; 6. Cambará do Sul; 7. São Francisco de Paula; 8. Terra de Areia; 9. Lagoa dos Patos; 10. São Francisco de Assis

abundant, and rich resource: *Araucaria* seeds. Furthermore, unprecedented high magnitude charcoal frequencies despite this more humid period appear to mark the onset of human landscape transformation associated with agricultural practices between around 4320 and 2980 cal. yr BP (3950 and 2850 ^{14}C yr BP).

The southern Brazilian highlands

The SBHs encompasses the southern Brazilian states of Rio Grande do Sul, Santa Catarina, and Paraná as well as part of Misiones Province, Argentina, and Paraguay (Fig. 1). The region is limited to the north by the Paranapanema River and to the south by the Jacuí-Ibicuí rivers. The SBHs decrease in altitude from east to west, from more than 1000 m close to the Atlantic coastal plain to 100 m in the Paraná and Uruguay rivers floodplains. The climate is mesothermic very humid with mean annual temperatures between 15–20^0C and 1500–2500 mm of mean annual precipitation. Temperature is mild in the central part of the plateau. The eastern area has higher elevations and a cold climate with sporadic snowfall during the winter months of June/July.

Four major vegetation types dominate the region including grasslands (Campos), *Araucaria* forest, semideciduous forest, and the Atlantic tropical forest (Fig. 1). All taxonomic names mentioned below follow Leite and Klein (1990). Campos vegetation dominates the southern lowland portion of the area. Modern highland vegetation is comprised of a mosaic of grasslands and *Araucaria* forests. Dominant families are the Poaceae, Cyperaceae, Asteraceae, Fabaceae, Caesalpinaceae, and Verbenaceae (Leite and Klein 1990). *Araucaria* forest is distributed along the states of Rio Grande do Sul, Santa Catarina, Paraná, and São Paulo, but is also present in some areas of Rio de Janeiro and Minas Gerais states, as well as in small areas of Misiones Province, Argentina and Paraguay. The tree, *Araucaria angustifolia*, commonly known as the Paraná-pine, with its characteristic umbrella shape crown, occurs above 600 m, but becomes more important as a canopy component above 800 m elevation. This species covers large areas between 24^0 and 30^0 S at elevations between 600 and 1400 m in southern Brazil, and in isolated islands between 18^0 and 24^0 at elevations 1400 to 1800 m in south-eastern Brazil (Hueck 1953; Rambo 1956). *A. angustifolia* occupies regions with an annual rainfall $>$ 1400 mm, with a minimum average temperature of *c.* 11·5^0C and a maximum temperature of 22^0C (Backes 1999). Before its commercial logging, and the expansion of cattle ranching and industrial agriculture in the region, *Araucaria* forest occupied *c.* 175,000 km^2 of the SBHs, but is now reduced to only 3% of its original cover (FUPEF 2001). *Araucaria* forest is mainly composed of *Araucaria angustifolia*, *Podocarpus lambertii*, *Ilex paraguayensis*, *Drymis brasiliensis*, *Symplocos uniflora*, and *Mimosa scabrella*. Other trees of importance are species in the Myrtaceae (*Myrceugenia* spp., *Eugenia* spp., *Myrciaria* spp.) and Lauraceae (*Ocotea* spp., *Nectandra* spp.). The tropical Atlantic forest occurs in southern Brazil as a belt along the Atlantic coastal plain and in the eastern slopes of the plateau at elevations up to 1000 m. The plain is widest near the boarder of Santa Catarina and Rio Grande do Sul states where it is as much as 200 km wide. These forests form one of the biodiversity hotspots recognised by Myers *et al.* (2000). Dominant trees are in the Euphorbiaceae (*Alchornea*), Arecaceae (*Euterpe*), Myrtaceae, Moraceae, Bignoniaceae, Lauraceae, and Sapotaceae (Leite and Klein 1990). The semideciduous forest grows along the Paraná and Uruguay river systems and the southern escarpment of the plateau following the tributaries up to 500–800 m elevation. In the Paraná basin this forest covers an area 100–150 km wide, and is mainly composed of *Alchornea triplinerva*, *Celtis* spp., *Gallesia*, *Copaifera langsdorfii*, and *Hymenea stilbocarpa*.

Evidence for Late Holocene vegetation changes

The southern Brazilian highlands have been a major focus of palynological research during the past decade making it one of the most intensely studied regions of South America. Ten pollen cores from the southern Brazilian states of Rio Grande do Sul, Santa Catarina, and Paraná, show marked changes in vegetation in the SBHs beginning at the end of the mid Holocene. During the initial part of the late-Holocene period between around 4480 and 1410 cal. yr BP, the climate became wetter. Consequently, *Araucaria* forest expanded to form a network of gallery forest along streams, although grassland vegetation dominated at a regional scale. Beginning about 1410–900 cal. yr BP, the climate become even wetter and less seasonal, which resulted in the replacement of grasslands by *Araucaria* forest in the southern sector of the plateau.

In Paraná State, the fossil pollen record from Serra Campos Gerais (SCG) (1200 m) (Fig. 2), indicates that between 2980 and 1440 cal. yr BP (2850 and 1530 ^{14}C yr BP) there was a slight increase in *Araucaria* forest abundance and higher percentages of tropical forest taxa. Behling (1997a) suggested that this was the first expansion of *Araucaria* forest from valley habitats into the adjacent highlands, while tropical forest tree populations became more extensive in the valleys. These patterns are associated with the highest percentages of charcoal particles detected in this record, an aspect that will be discussed below in more detail.

Between 1440 and 580 cal. yr BP (1530 and 530 ^{14}C yr BP), the pollen record shows a major increase in *Araucaria* forest and the tropical forest group remains steady. Behling (1997a) indicates that the higher percentages of *Araucaria* pollen clearly show that the wettest climate, without a significant annual dry season, was only established during this period creating a landscape characterised by a mosaic of open grasslands and *Araucaria* forest. The charcoal record shows that fires during this period were frequent, but not as common as between 2980 and 1440 cal. yr BP (2850 and 1530 ^{14}C yr BP). In the highlands of the neighbouring state of São Paulo, the Morro de Itapeva pollen core shows a change to more humid conditions at *c.* 3200 cal. yr BP (3000 ^{14}C yr BP) (Behling 1997b).

In the state of Santa Catarina, at the Serra da Boa Vista core (1160 m) there is an initial increase in *Araucaria* forest taxa (*Araucaria*, *Podocarpus*, *Mimosa*, *Ilex*, *Symplocos*) recorded after *c.* 3760 cal. yr BP (3460 ^{14}C yr BP) (Ledru *et al.* 1998). At Morro da Igreja (1800 m) the pollen sequence show an initial expansion of *Araucaria* forest at *c.* 2430 cal. yr BP (2390 ^{14}C yr BP). Subsequently, both the Morro da Igreja and the Serra do Rio Rastro (1420 m) fossil pollen records show a pronounced expansion of *Araucaria* forest as indicated by high percentages of *Araucaria* pollen and spores of the tree fern *Dicksonia sellowiana*, which indicate the establishment of more humid climate conditions after *c.* 900 cal. yr BP (1000 ^{14}C yr BP) (Fig. 3) (Behling 1995).

Located in the highlands of north-eastern Rio Grande do Sul state, Cambará do Sul (1040 m) provided one of the more recent and well-dated pollen sequences for the region (Fig. 4) (Behling and Pillar 2007; Behling *et al.* 2004). Similar to the records in the highlands of Paraná and Santa Catarina states, an initial expansion of *Araucaria* forest, which at that time, formed gallery forests along streams within a landscape dominated by grassland vegetation, was observed around 4320 cal. yr BP (3950 ^{14}C yr BP). By that time, the Atlantic forest was well established on the upper coastal slopes, located 6–10 km from the study site. Carbonised particles abruptly increased in abundance during this period.

Between *c.* 1100 and 430 cal. yr BP (1140 and 410 ^{14}C yr BP), the representation of Campos pollen taxa, primarily Poaceae, was markedly lower than in the previous period and its abundance continued to decrease toward the top of the zone (from 55 to 24%). Pollen of *Araucaria* forest increased continuously (from 39 to 80%) indicating a remarkably strong expansion of this forest, such that within a period of 100 years it replaced the Campos vegetation. At *c.* 1100 cal. yr BP, there were fewer carbonised particles than before, although fires continue to be frequent in the wider region where patches of grassland still existed (Behling *et al.* 2004).

In the nearby São Francisco de Paula sequence, pollen preservation in deposits started after 4480 cal. yr BP (4000 ^{14}C yr BP) indicating wetter climatic conditions (Behling *et al.* 2001). Here the expansion of *Araucaria* started at *c.* 990 cal. yr BP (1060 ^{14}C yr BP). Other pollen records from the highlands of Rio

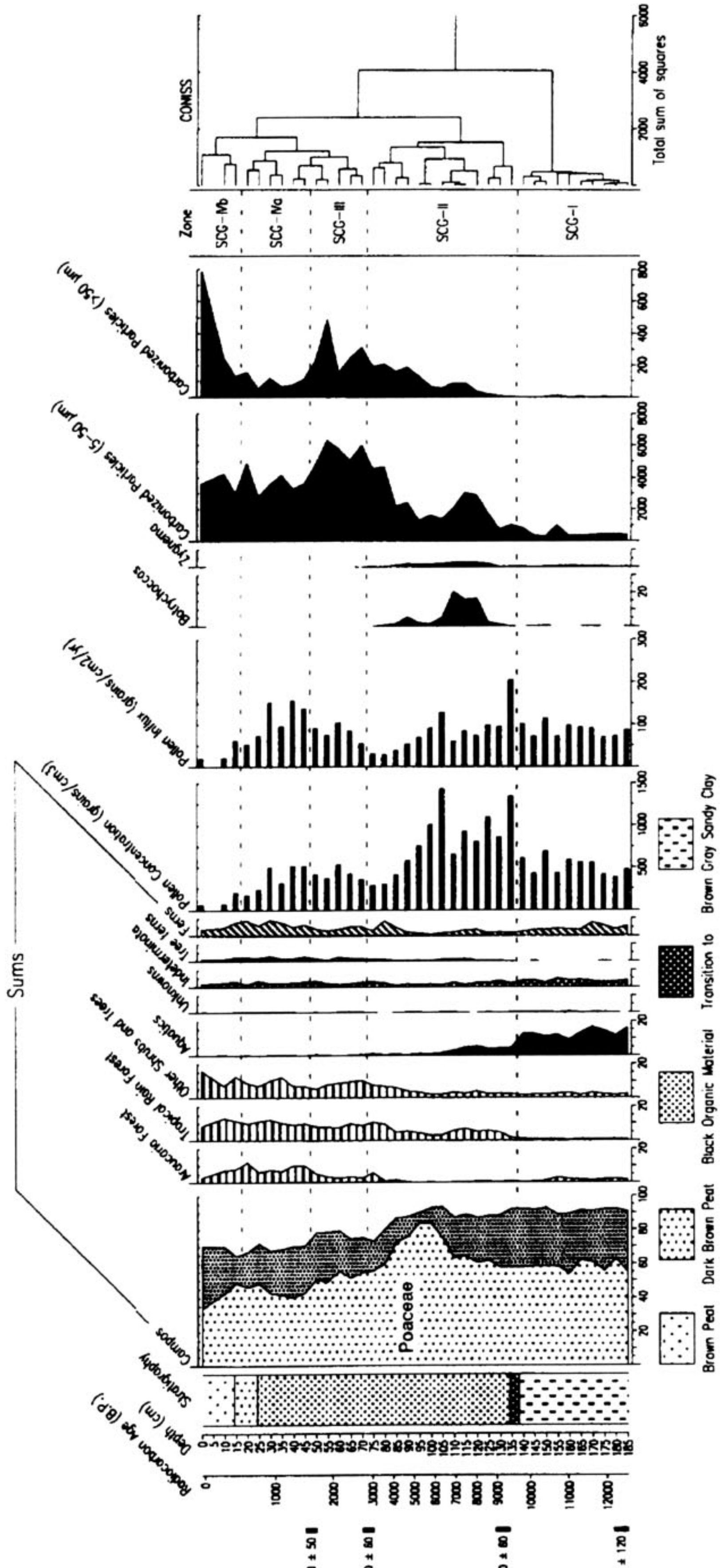

Figure 2 Serra Campos Gerais pollen profile (Behling 1997a)

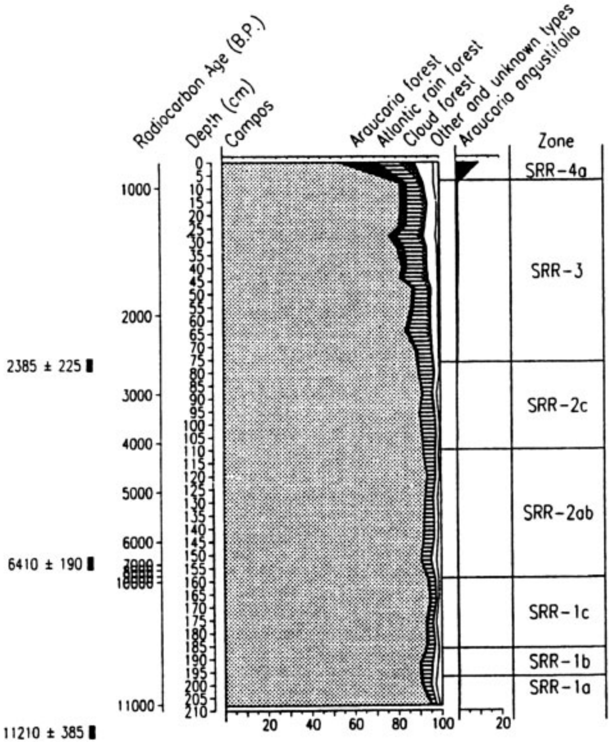

Figure 3 **Serra do Rio Rastro pollen profile (Behling 2002)**

Grande do Sul state at Aparados da Serra (1000 m) and three pollen cores in the lowlands including São Francisco de Assis (100 m), Terra de Areia (0 m), and Lagoa dos Patos (0 m) recorded an increase in forest taxa including *Araucaria* and *Podocarpus* after *c.* 2590 cal. yr BP (2500 ^{14}C yr BP). An expansion of *Araucaria* forest on the plateau and of tropical and semidecidous forest along the escarpment indicative of higher moisture and higher temperature, was inferred (Behling *et al.* 2005; Ledru *et al.* 1998). At present the radiocarbon date of *c.* 1100 cal. yr BP from Cambará do Sul is the best date for the pronounced expansion of *Araucaria* forest in the SBHs. Fig. 5 shows *Araucaria angustifolia* pollen curves from most representative pollen sequences discussed in the text.

The change to more humid conditions at around 4480 cal. yr BP (4000 ^{14}C yr BP) was also recorded in the neighbouring coastal Atlantic tropical forest (e.g., Behling and Negrelle 2001; Bissa *et al.* 2000; Garcia *et al.* 2004; Scheel-Ybert 2000), the cerrados of Central Brazil (Salgado-Labouriau 1997), and the grasslands of south-eastern Brazil (Behling *et al.* 2005) and Uruguay (Iriarte *et al.* 2004; Iriarte 2006a).

In summary, the first Holocene expansion of *Araucaria* forest at the expense of Campos grasslands in the SBHs started between 4480 and 3200 cal. yr BP. A later, greater expansion of *Araucaria* forest began between around 1410 and 900 cal. yr BP. Specifically, this event was dated to *c.* 1100 cal. yr BP in Cambará do Sul, 990 cal. yr BP in São Francisco de Paula in Rio Grande do Sul, 900 cal. yr BP in Morro da Igreja and Serra do Rio Rastro in Santa Catarina and at *c.* 1440 cal. yr BP in the Serra Campos Gerais, Parana State. In the highlands of Paraná, the expansion of *Araucaria* forest resulted in

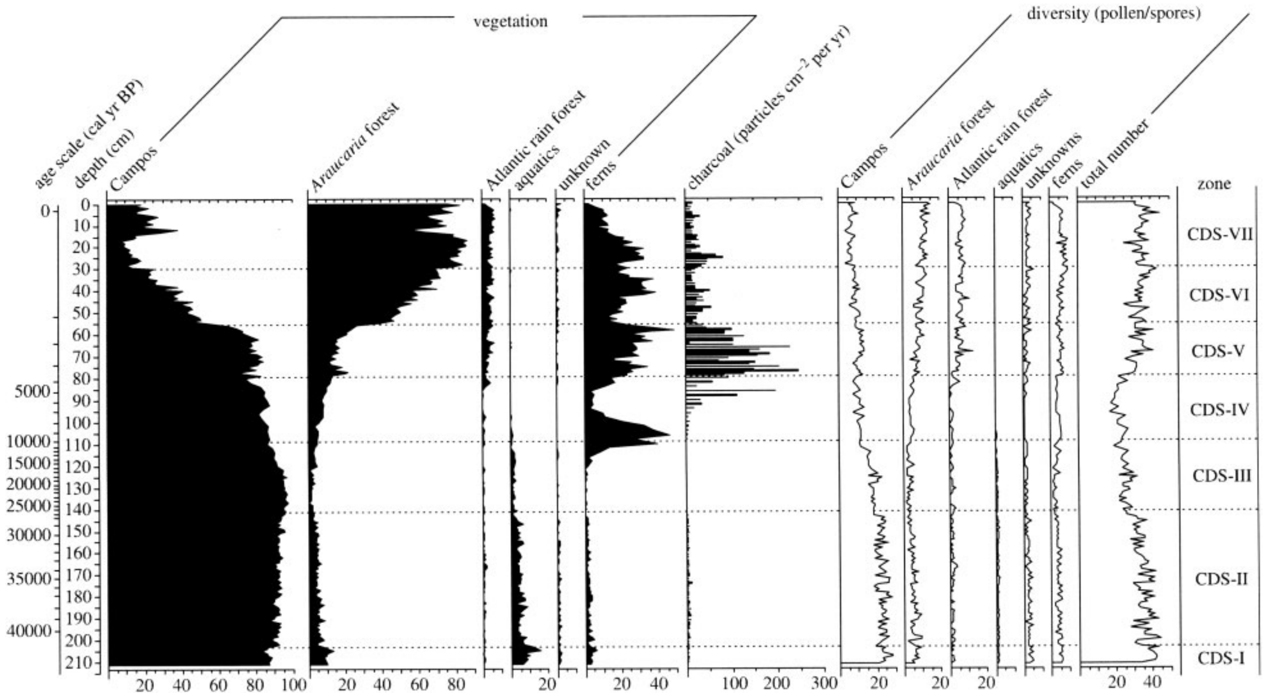

Figure 4 **Cambara do Sul pollen profile (Behling and Pillar 2007)**

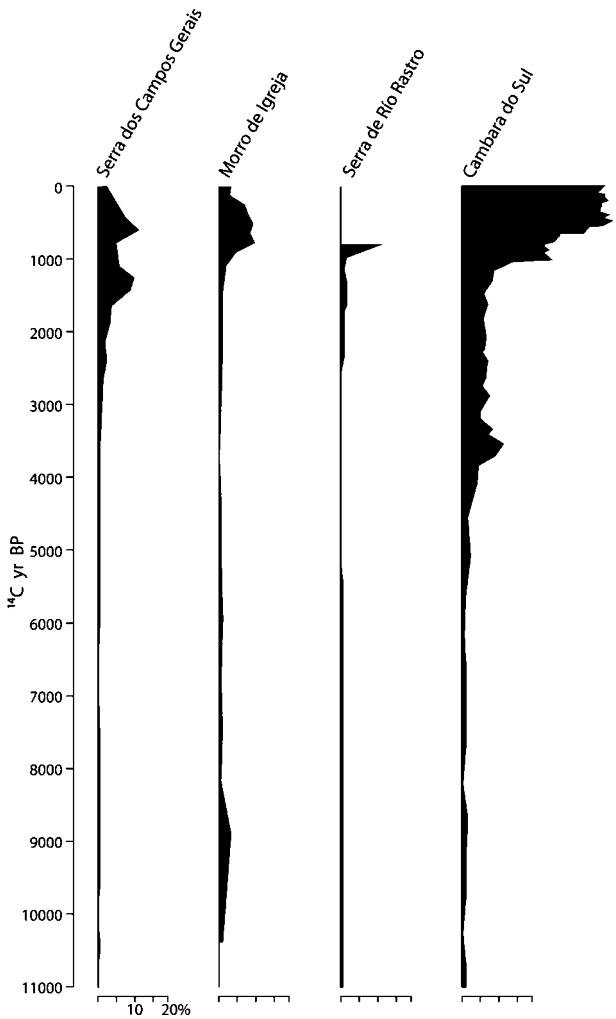

Figure 5 Araucaria angustifolia pollen percentage curves from selected pollen diagrams

a mosaic of grasslands and *Araucaria* forest patches, while in Rio Grande do Sul, grassland vegetation was replaced by *Araucaria* forest.

The Taquara/Itararé Tradition

First defined by Menghin (1957) as El Doradense in Misiones Province, this archaeological tradition is known as Itararé in Paraná (Chmyz 1967) and Taquara in Santa Catarina and Rio Grande do Sul states (Miller 1967). Following Beber (2004), we use the term Taquara/Itararé Tradition for the sake of convenience. Dating back to *c.* 2220 cal. yr BP (2180 ^{14}C yr BP) and extending to present, this broadly-defined tradition, is mainly characterised for its diagnostic ceramics, the construction of pithouses in the highlands, and its elaborated mound and enclosure complexes. The brief summary and the compilation of radiocarbon dates presented below has been obtained from data published by Brazilian researchers over the last decades (Beber 2004; 2005; De Masi 2005; Noelli 2000; Prous 1992; Ribeiro 1999/2000; Schmitz 1988; 1999/2000; Schmitz 2002). The reader is referred to these works for more detailed information.

Taquara/Itararé ceramics are characterised by simple, tall, small vessels exhibiting fine walls. They are generally tempered with sand and hematite grains, have homogenous paste, and reduced firing. Decoration is more frequent in the southern Taquara phases and includes several incised types, punctuations, as well as finger nail and basket impressions. The economy of these groups is thought to be based mainly on the exploitation of *Araucaria* seeds complemented with horticulture, hunting, and fishing (Beber 2005; Ribeiro 1999/2000; Schmitz 2001/2002).

Five types of archaeological sites are associated with the Taquara/Itararé Tradition including pithouses, open air sites, geometric earthworks and mounds, caves and galleries. Generally constructed on lateritic soils and decomposed basalt, pithouses occur above 400 m, but are concentrated between 600–1200 m elevation closely overlapping the distribution of *Araucaria* forest. Pithouses are generally located in the upper slope and flat tops of interfluvial ridges close to small streams. The diameter of a pithouse ranges between 2 m and 20 m, but the majority do not exceed 5 m. Pithouses are habitation sites containing the remains of everyday activities including hearths, post-holes, ceramic sherds, lithic tools and debris, and charred *Araucaria* seeds (Fig. 6) (Beber 2005; Ribeiro 1999/2000; Schmitz 1988). The tough, double-coated *Araucaria* seeds, which bear a first hard layer surrounding the seed that accounts for 22% of the seed's dry weight (Bello-Perez *et al.* 2006; Cordenunsi *et al.* 2004), have been the only charred macro-botanical remains recovered in pithouses. Pithouses may be isolated or form villages of up to 68 houses. The ground plan of pithouse villages may exhibit a linear layout paralleling a stream, may be arranged in parallel lines, or form an approximate circle (Prous 1992: 313). Surface sites associated with pithouse clusters are common and have been interpreted as probable special-activity areas such as agricultural plots and quarry sites (e.g., Beber 2005; De Masi 2005; Kern *et al.* 1989; Ribeiro and Ribeiro 1985).

At lower altitudes, in the upper river valleys and the southern escarpment of the plateau where *Araucaria* forest is sparser and semidecidous forest dominates, pithouses become rare and surface sites are more abundant. In some areas like the lower Antas and Pardo rivers, situated below 600 m elevation, Taquara/Itararé surface sites are characterised

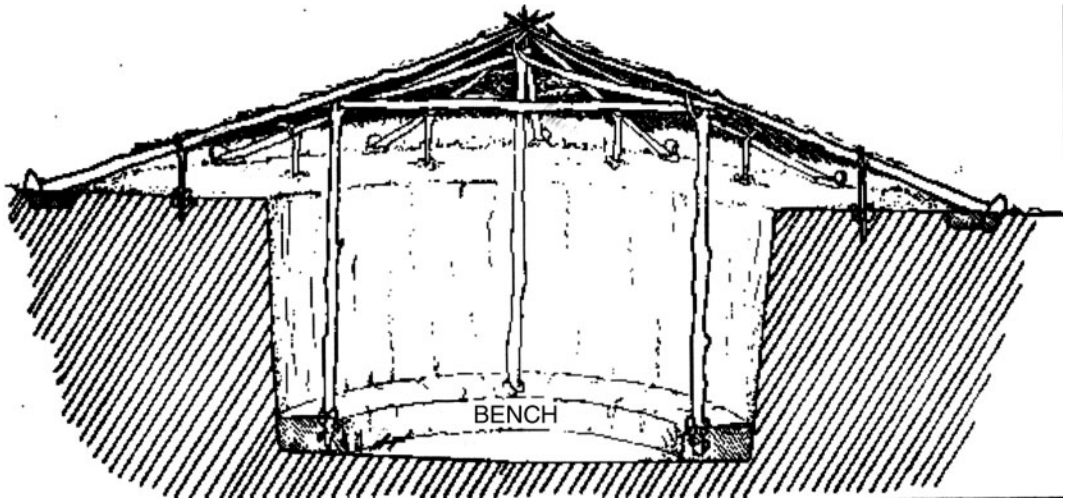

Figure 6 Sketch diagram of a pithouses (La Salvia 1983)

by discrete circular patches of dark earth (*terra preta*) forming villages that cover up to 4000 m^2 (Miller 1967, 20; Ribeiro 1991 cited in Beber 2004).

Other types of site associated with Taquara/Itararé Tradition were characterised by circular, elliptical, rectangular, and key-shape earthworks generally located in the most prominent hills of the area. The rims were 30–50 cm tall, 3–4 m wide, and 20–200 m in diameter. Their formal layout and lack of domestic debris indicate that these sites were ceremonial spaces where geographically dispersed groups came together to bury an important chief, host inter-group gatherings, foster group reciprocity, forge inter-group alliances or perform cyclical rituals (Beber 2005; Cope and Saldanha 2002; Schmitz and Becker 1991). Some of them, like the complex of earthworks in El Dorado (Misiones, Argentina) spread over 200 ha and are constituted by more than 8 circular enclosures (Menghin 1957; Wachnitz 1984). On-going excavations by Iriante and colleagnes in the larger of these mound and enclosure centres are revealing a complex history of construction stages and use spanning between 703–518 cal. yr BP, some of which appear to have dramatically altered the appearance of the enclosure and its associated mound. Two other types of site have been associated with the Taquara/Itararé people: collective burials in caves, and galleries of unknown use dug into consolidated soils (Rohr 1971).

Human-environment interactions in the southern Brazilian highlands: the last 1500 years

The development of the Taquara/Itararé tradition and the expansion of Araucaria forest

Some important patterns emerged from the comparison of the recent palynological and archaeological data from the SBHs. In the first place, the data showed that the colonisation of the SBH by the Taquara/Itararé Tradition was strongly associated with the marked expansion of *Araucaria* forest during the late Holocene. The available 71 radiocarbon dates indicated that Taquara/Itararé sites began to spread in the second millennium BP, became more common around 1500 cal. yr BP and peaked after 1000 cal. yr BP (Table 1, Fig. 7). This pattern was also supported by plotting the best-dated sequences from the clusters of pithouses that occurred in the north-east of Rio Grande do Sul state (Esmeralda, Vacaria, Bom Jesus, and São Francisco de Paula) against the *Araucaria* pollen percentage changes from the nearby Cambará do Sul pollen site (see Figs. 1 and 8). From the 33 existing radiocarbon dates of pithouses for this region, 79% of the dates are younger than 1000 cal. yr BP, 15% lie between 1500 and 1000 cal. yr BP, and the remaining 6% of dates are older than *c.* 1500 cal. yr BP (Fig. 8).

As *Araucaria* forest began to expand in the highlands, pre-Hispanic groups may have been motivated to migrate or foray seasonally to the highlands to collect *Araucaria* seeds in areas of concentrated production. The replacement of grassland by *Araucaria* forest that took place between 1410 and 900 cal. yr BP (1500 and 1000 ^{14}C yr BP) may have allowed higher permanent settlement in the highlands. The cultural development adapted to this new environment is inferred based upon the proliferation of Taquara/Itararé pithouse villages. Sites located within ecotones comprised by *Araucaria* forest, Campos, and deciduous forests, would have been privileged locations in terms of abundance and diversity of resources.

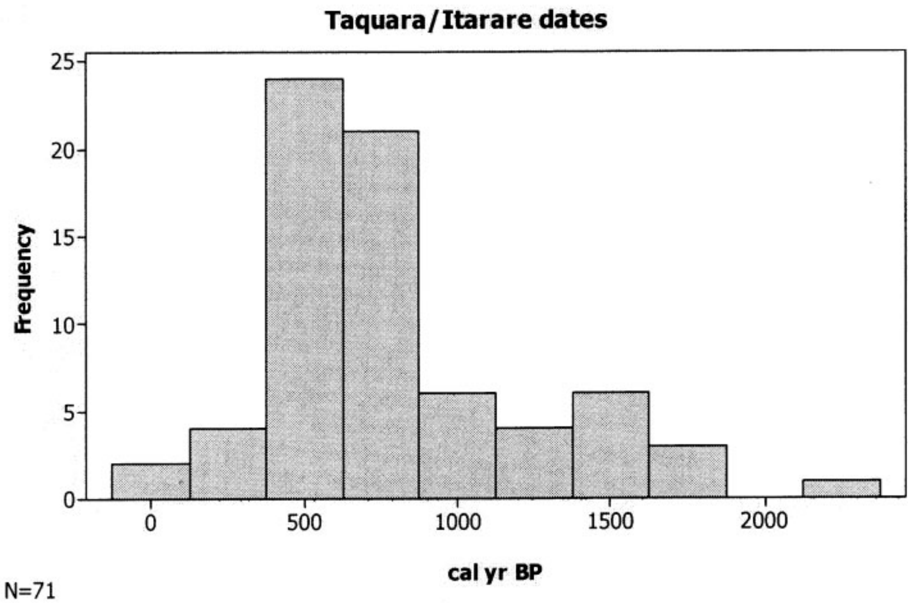

Figure 7 Histogram of Taquara/ Itararé dates

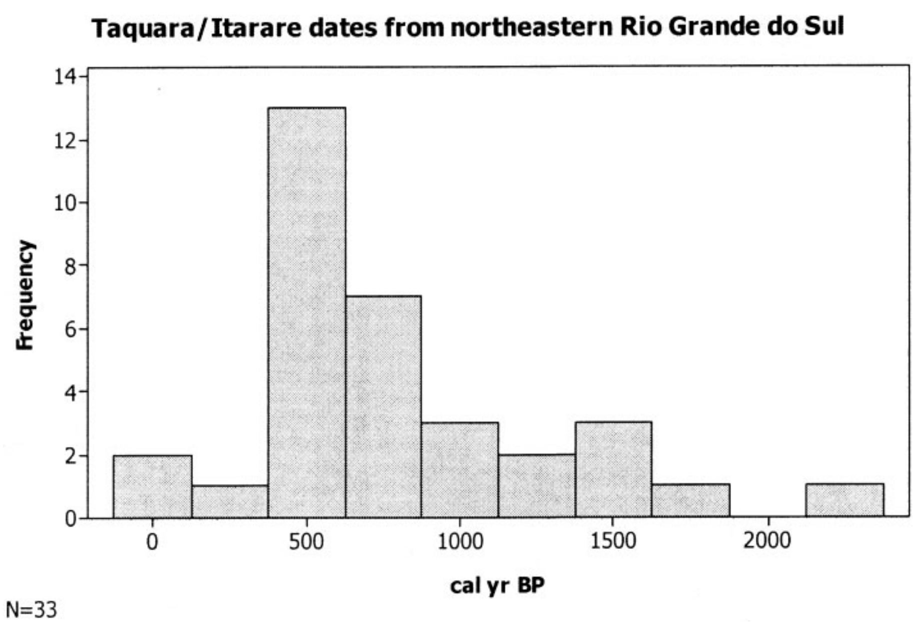

Figure 8 Histogram of Taquara/ Itararé dates from Esmeralda, Vacaria, Bom Jesus, Caxias do Sul, and Saô Francisco de Paula sites in Rio Grande do Sul state

Araucaria seeds, called pinhão, were a major element in the diet of the ethnohistorically and ethnographically recorded indigenous people living in and around the range of the *Araucaria* trees (Mabilde 1988; Metraux 1946). *Araucaria* trees are very productive. Each tree produces up to thirty large cones, each of which contains an average of 112 seeds (5·8 cm long) (FAO 1995). Unfortunately, we do not posses data about the modern density of *Araucaria* trees in different regions, but the pollen data suggest that they were very abundant in the SBH since *c.* 1410–900 cal. yr BP (1500–1000 ^{14}C yr BP).

Araucaria seeds are a good source of starch (37%), dietary fibre, Mg, and Cu. They also have a low content of protein (~3%) and lipids (~1·3%), which is comparable to other starchy foods such as rice and beans (Bello-Perez *et al.* 2006; Cordenunsi *et al.* 2004). The seeds are mainly harvested during the months of March and June, but production is meagre during the spring and summer (October–February). However, the seeds of different subspecies of *Araucaria angustifolia* are ripe during different months of the year, which potentially make them available all year round (Beber 2005; Reitz and Klein

Table 1 Taquara/Itararé Tradition dates from Riogrande do Sul (RS), Santa Catalina (SC) and Parana (PR) states. The calibration of the radiocarbon dates have been carried out after CALPAL (Weninger *et al.* 2004)

Provenance			^{14}C age	64% range	Calendric	
Site	Locality	Lab no.	yr BP	cal BP	age cal. BP	References
RS-A-27	Vacaria, RS	Beta 144246	30±50	148–31	59±89	Schmitz *et al.* 2002
RS-A-27	Vacaria, RS	Beta 144243	40±60	227–23	102±125	Schmitz *et al.* 2002
RS-AN-03	Bom Jesus, RS	Beta 166586	80±50	235–17	126±106	Cope and Saldanha 2002
RS-VZ-44	Tenente Portela, RS	SI 599	160±70	267–37	151±114	Miller 1971
	Cruz Machado, PR	SI 692	255±100	424–106	265±159	Chymz 1969
	Torre de Pedra, SP	Gsy	270±60	427–190	309±118	DeBlasis 1996
SC-CL-10	Urubici, SC	SI 597	330±90	471–296	384±87	Schmitz 1988
RS-PE-10b	Esmeralda, RS	SI 6559	355±50	474–341	408±66	Ribeiro and Ribeiro 1985
RS-AN-03	Bom Jesus, RS	Beta 166584	370±50	483–345	414±69	Cope and Saldanha 2002
RS-A-29	Vacaria, RS	Beta 178089	370±50	483–345	414±69	Rogge 2005
RS-A-29	Vacaria, RS	Beta 153834	380±60	489–345	417±72	Schmitz *et al.* 2002
RS-PE-10b	Esmeralda, RS	SI 6556	390±50	494–350	422±72	Ribeiro and Ribeiro 1985
RS-VZ-25	Porto Lucena, RS	SI 600	400±100	512–334	423±89	Miller 1971
RS-PE-28a	Esmeralda, RS	SI 6562	420±55	510–358	434±76	Ribeiro and Ribeiro 1985
RS-PE-10a	Esmeralda, RS	SI 6558	465±40	532–498	515±17	Ribeiro and Ribeiro 1985
PR-UB-4	Ubiratã, PR	SI 2192	470±95	594–375	485±109	Chmyz 1976
RS-A-27	Vacaria, RS	Beta 144245	520±60	662–520	571±51	Schmitz *et al.* 2002
RS-AN-3	Bom Jesus, RS	Beta 166585	550±40	626–538	582±44	Cope and Saldanha 2002
PR-CT-53	Campo Largo, PR	Beta 22646	558±50	631–541	586±45	Chmyz 1995
PR-CT-93	Curitiba, PR	Beta 180905	580±60	639–549	594±45	Chmyz et al 2003
PR-MN-4	Middle Iguazu River, PR	SI 6396	595±60	643–555	599±44	Chmyz et al 2003
BS19	Bairro da Serra	Gsy 10040	595±50	641–558	600±41	DeBlasis 1996
PR-UV-12	Cruz Machado, PR	SI 691	605±120	673–528	601±72	Chymz 1969
RS-68	Caxias do Sul, RS	SI 608	620±90	662–554	608±54	Schimtz 1988
PR-UV-12	Bituruna, RS	SI 691	623±120	687–540	614±73	Schmitz 1988
RS-37/127	Caxias do Sul, RS	SI 604	630±70	657–564	611±46	Schimtz 1988
RS-C-12	São Sebastiao do Caí, RS	SI 205	630±205	791–434	613±178	Rogge 2005
RS-PE-26a	Esmeralda, RS	SI 6561	635±45	653–571	612±41	Ribeiro and Ribeiro 1985
RS-PE-28a	Esmeralda, RS	SI 6563	650±55	661–572	617±44	Ribeiro and Ribeiro 1985
PR-CT-93	Curitiba, PR	Beta 180906	660±60	666–573	620±46	Chmyz *et al.* 2003
PR-UV-11	Cruz Machado, PR	SI 1010	680±70	684–576	630±54	Chymz 1969
PR-CT-93	Curitiba, PR	Beta 180907	680±70	684–576	630±54	Chmyz et al 2003
RS-A-29	Vacaria, RS	Beta 153842	680±80	575–694	635±59	Schmitz et al. 2002
RS-A-08	São José dos Ausentes, RS	SI 2343	700±60	694–582	638±56	Schmitz 1988
RS-A-29	Vacaria, RS	Beta 178090	710±60	705–585	645±60	in Rogge 2005
RS-C-14	São Sebastião do Caí, RS	SI 1198	745±65	739–652	696±43	in Rogge 2005
PR-UB-4	Ubiratã, PR	SI 2194	735±95	772–596	684±88	Chmyz 1981
PR-UB-1	União da Vitória, PR	SI 141	800±50	772–694	733±39	Chmyz 1968
	Tapera, SC	SI 243	800±70	815–691	753±62	Smithsonian in Noelli 2000
PR-UV-12	Cruz Machado, PR	SI 892	810±90	864–690	777±87	Chymz 1969
RS-VZ-43	Tenente Portela, RS	SI 598	830±60	848–708	778±70	Miller 1971
RS-37/127	Caxias de Sul, RS	SI 606	840±60	865–714	790±75	Schmitz 1969
PR-CT-53	Campo Largo, PR	Beta 22644	848±70	877–717	797±80	Chmyz 1995
PR-CT-93	Curitiba, PR	Beta 180904	850±50	866–723	795±71	Chmyz *et al.* 2003
PR-UB-4	Ubiritã, PR	SI 2193	855±95	890–714	802±88	Chmyz 1978
RS-A-27	Vacaria, RS	Beta 144244	870±50	881–742	812±69	Schmitz *et al.* 2002
RS-A-27	Vacaria, RS	Beta 144247	870±60	884–738	811±73	Schmitz *et al.* 2002
RS-RP-164b	Santa Cruz do Sul, RS	SI 4066	915±145	985–729	857±128	in Rogge 2005
PR-CT-93	Curitiba, PR	Beta 180903	940±70	919–783	851±68	Chmyz *et al.* 2003
RS-P-27	Bom Jesus, RS	SI 812	950±80	933–783	858±75	Beber 2004
RS-37/127	Caxias de Sul, RS	Beta 153841	960±60	926–804	865±61	in Rogge 2005
RS-U-2	S. Fco. De Paula, RS	SI 808	970±95	966–792	879±87	Schimtz 1988
RS-U-35	Concórdia, SC	SI 825	975±90	972–796	884±88	Beber 2004
RS-AN-3	Bom Jesus, RS	Beta 166588	1000±40	951–843	897±54	Cope and Saldanha 2002
RS-37/127	Caxias do Sul, RS	SI 602	1140±40	1152–792	972±180	Schimtz 1988
	Tapera, SC	SI 245	1140±180	1237–881	1059±178	Chmyz 1976
RS-S-61	Taquara, RS	SI 409	1190±100	1228–1009	1119±109	in Rogge 2005
RS-PF-01	Passo Fundo, RS	SI 601	1300±70	1282–1140	1211±71	Schmitz 1988
RS-37/127	Caxias do Sul, RS	SI 605	1330±100	1327–1128	1228±99	Schmitz 1969
RS-S-282	Sapiranga, RS	SI 414	1380±110	1394–1182	1288±106	in Rogge 2005
RS-A-2	S. Fco. de Paula, RS	SI 806	1385±95	1384–1202	1293±91	Schmitz 1988
PR-UV-17	União da Vitória, PR	SI 2197	1475±65	1465–1326	1396±69	Chmyz 1969
RS-37/127	Caxias do Sul, RS	SI 603	1480±70	1477–1329	1403±74	Schmitz 1969
RS-A-2	S. Fco. de Paula, RS	SI 805	1515±105	1529–1338	1434±95	Schmitz 1988

1966). The seeds could be eaten raw, roasted, or grounded into a paste. Pine nuts could be stored in tightly closed baskets soaked in water for a month and a half. *Araucaria* trees also provide an accessible and renewable wood supply. Because *Araucaria* nuts are also an important item in the diet of several faunal resources targeted by humans, including a variety of mammals, reptiles, and birds, its fruiting period should have coincided with an increase in the availability of game. The combination of *Araucaria*-nut collection and other wild plants, combined with the growing of tropical cultigens and hunting, would have been able to support rather sedentary populations in the highlands (Schmitz 2001/2002). To what extent did Taquara/Itararé groups manipulate or encourage the expansion of *Araucaria* forest is an important issue that requires further clarification through further archaeological and paleoecological research.

Landscape transformation related to agricultural practices

During the late Holocene there is a clear pattern in certain regions characterised by the increase of carbonised particles when *Araucaria* and the tropical forest began to expand and a decline in carbonised particles as climates became wet and less seasonal about 1410 and 900 cal. yr BP (1500 and 1000 ^{14}C yr BP). As mentioned earlier, the SCG pollen record shows an abrupt increase in charcoal particles between 2980 and 1440 cal. yr BP (2850 and 1530 ^{14}C yr BP) with a subsequent decline associated with the expansion of *Araucaria* forest beginning around 1440 cal. yr BP. A similar pattern was recorded in the southern highlands at Cambará do Sul, where the pollen diagram showed a sudden rise in charcoal abundance between *c.* 4320 and 1100 cal. yr BP (3950 and 1140 ^{14}C yr BP), followed by a sharp decline.

Two aspects suggest that these fires were not natural and were predominantly set by humans. The first was that by the time the fires increase dramatically in SCG and CDS, the climate was wetter and less seasonal than previous periods; arguing against an increase in natural fires triggered by droughts. The second was the frequency and magnitude of these charcoal increases. The abrupt and frequent occurrence of charcoal particles at 4320 (CDS) and 2798 (SCG) cal. yr BP in systems that had not previously been fire prone is a strong indicator of human occupation (Bush *et al.* 2000; Bush *et al.* 2007). These data suggest the onset of slash-and-burn agriculture within the semideciduous forest that grew along the major tributaries up to 500–800 m elevation, and in the Atlantic tropical forest in the case of CDS.

These records provide support for the idea that well before Taquara/Itararé groups established a more permanent habitation of the highlands, pre-Hispanic groups were practicing slash-and-burn agriculture at lower areas beginning around 4320 cal. yr BP. Unfortunately, the archaeological record of that period is very incomplete and poorly understood. New data from surface sites in the lower Canoas River dating to *c.* 2540 cal. yr BP (2450 ^{14}C yr BP) appear to indicate that the occupation of the lowland by Taquara/Itararé groups may have preceded the colonisation of the highlands (De Masi 2005). Further clarification of these patterns requires more archaeological and palynological research in lowland areas.

Both records show a decline in charcoal around 1000 yr BP but the continued presence of fine charcoal particles, which remained much higher than pre-4320 cal. yr. BP levels, suggests that fires were still frequent at a regional scale. This pattern suggests that Taquara/Itararé people continued to practice slash-and-burn agriculture at low sites, while *Araucaria* forest expanded and replaced grassland vegetation in the highlands.

The charcoal record also gives support to the idea that Taquara/Itararé groups practiced a mixed economy combining the collecting of *Araucaria* nuts in the highlands with the practice of slash-and-burn agriculture at lower altitudes dominated by

Table 1 (Continued)

Provenance			^{14}C age	64% range	Calendric	
Site	Locality	Lab no.	yr BP	cal BP	age cal. BP	References
RS-40	Caxias do Sul, RS	SI 607	1520±90	1517–1348	1433±84	Schmitz 1969
SC-IC-01	Içara, SC	Beta 72196	1580±60	1533–1412	1473±60	Schmitz 1995
RS-S-328	San Antonio, RS	SI 2345	1655±65	1655–1462	1559±96	Smithsonian in Noelli 2000
RS-S-239	San Antonio, RS	SI 2344	1740±65	1743–1582	1663±80	Smithsonian in Noelli 2000
RS-P-12	Bom Jesus, RS	SI 813	1810±85	1839–1633	1736±103	Schmitz and Brochado 1972
SC-CL	São Joaquim, SC	SI 811	1920±50	1925–1816	1871±54	Smithsonian in Noelli 2000
RS-AN-3	Bom Jesus, RS	Beta 166587	2180±40	2290–2143	2217±73	Cope and Saldanha 2002

semideciduous forest, which has been hypothesised by several authors (e.g., Beber 2005; Kern *et al.* 1989; De Masi 2005; Ribeiro 1999/2000; Schmitz 2001/2002). The abundance of plant processing tools recovered in low altitudes sites, including stone axes, mortars, and handstones, also provides indirect evidence for the importance of food-production in the subsistence economy of these groups.

At this point, one may ask what is the primary evidence for agriculture in the region. The study of the plant component of pre-Hispanic subsistence of the La Plata Basin is at a very early stage. Few projects have systematically applied archaeobotanical recovery techniques and, thus, there is a paucity of primary data to provide direct evidence of prehistoric plant use and economy. In addition to the recovery of carbonised *Araucaria* nuts in pithouse habitation surfaces, maize cobs and squash seeds were recovered associated with burials dated to *c.* 1740 cal. yr BP (1810 ^{14}C yr BP) at the at the Abrigo do Matematico cave in the Bom Jesus locality, Rio Grande do Sul (Miller 1971). New evidence for the earlier presence of cultigens is beginning to accumulate. Maize (*Zea mays*) pollen was recorded at the São Francisco de Assis pollen sequence in the southern part of the plateau by *c.* 1960 cal. yr BP (1950 ^{14}C yr BP) (Behling *et al.* 2005).

The presence of these relatively early dates for domesticated plants in the SBHs should come as no surprise. Charcoal analysis from six shell mounds along the southern coast of the state of Rio de Janeiro, Brazil, dated between c 5500 BP and 1400 BP, documented for the first time the use of yams (*Dioscorea* sp.) in addition to palm and fruit trees in this region (Scheel-Ybert 2001). The study of dental wear patterns from 46 adult crania from the Preceramic Corondo site (Rio de Janeiro State), dated between 4740 and 3200 cal. yr BP (4200–3000 ^{14}C yr BP), documented high caries rates, suggesting these Archaic populations had a high-consumption of starchy plants (Turner and Machado 1983). In the wetlands of south-eastern Uruguay, phytolith and starch grain analysis documented the presence of maize, squash, *Phaseolus* beans, and *Canna* and *Calathea* tubers starting shortly after *c.* 4740 cal. yr BP (4190 ^{14}C yr BP) (Iriarte *et al.* 2004; Iriarte 2006b; Iriarte 2007).

The increasing role of domestic plants in the subsistence economies of the region since the mid-Holocene warrants renewed consideration in the light of growing palynological and microfossil botanical data. The application of appropriate techniques for botanical recovery in such acidic and clayey soils including phytolith, starch grains, and parenchyma (plant tissues) analyses in tandem with flotation, will allow us to answer major questions related to the role of domestic and wild plants in the economy of the Taquara/Itararé Tradition, as well as to examine the transition and specific mechanisms that led to the adoption of domesticates and the spread of agriculture in the region.

Conclusions

Recent archaeological and palaeoecological data in the SBHs allow us to carry out much more informed comparative analyses between regional-scale cultural sequences and their environments. The examination of pollen cores from the SBHs coupled with the archaeological record for the region indicates that the development of the Taquara/Itararé Tradition in strongly associated with the advance of *Araucaria* forest in the region during the late Holocene. The frequency of radiocarbon dates indicates a more intense human occupation of the SBHs after *c.* 1410 cal. yr BP, which peaks after around 900 cal. yr BP. The appearance of pithouse villages in addition to large and elaborate ceremonial centres is also a reflection of more permanent and territorial populations in the region.

The newly available resource, *Araucaria* seeds, appears to have played a major role in the subsistence economy of these groups allowing them to settle the highlands more permanently and at greater densities than before. Ecotonal areas where *Araucaria* forest, semideciduous forest, and grasslands converge may have been particularly attractive places in terms of abundance and diversity of resources. Mounting evidence also points to an increasing use of domesticated plants by these populations in addition to the collection of *Araucaria* nuts, other wild plants, hunting, and fishing. The charcoal records from SCG and CDS suggest that slash-and-burn agriculture at lower altitudes started *c.* 4320 cal. yr BP. Further clarification of these patterns requires more archaeological and palynological research in lowland areas.

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