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The Paleobiolinguistics of Domesticated Chili Pepper (*Capsicum* spp.)

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Abstract: *Paleobiolinguistics employs the comparative method of historical linguistics to reconstruct the biodiversity known to human groups of the remote, unrecorded past. Comparison of words for biological species from languages of the same language family facilitates reconstruction of the biological vocabulary of the family's ancient proto-language. This study uses paleobiolinguistics to establish where and when chili peppers (*Capsicum *spp.) developed significance for different prehistoric Native American groups. This entails mapping in both time and geographic space proto-languages for which words for chili pepper reconstruct. Maps show the broad distribution of* Capsicum *through Mesoamerica and South America mirroring its likely independent domestication in these regions. Proto-language dates indicate that human interest in chili pepper had developed in most of Latin America at least a millennium before a village-farming way of life became widespread.*

Key Words: Archaeobotany, *Capsicum* spp., crop origins, historical linguistics, Native American Indians, paleobiolinguistics, plant domestication, plant genetics

This is the second in a series of papers each presenting paleobiolinguistic (PBL) maps of a single crop domesticated in the New World. The first, Brown et al. (2013), provides maps for squash (*Cucurbita* spp.). Papers projected for publication in *Ethnobiology Letters* include treatments of manioc (*Manihot esculenta*), maize (*Zea mays*), beans (*Phaseolus* spp.), and tobacco (*Nicotiana* spp.). Our ultimate goal is to produce an online compendium, *Paleobiolinguistic Atlas of New World Crops*, in which maps for at least 30 botanical taxa are presented. Papers appearing in *Ethnobiology Letters* will present PBL maps accompanied by brief background discussions of crop-origins studies from archaeology and botany.

The method and theory of paleobiolinguistics is discussed in detail in preceding studies (Brown et al. 2013; Brown 2006a,b, 2010). A brief review of highlights is provided here. The comparative method of historical linguistics has been used for around 150 years to reconstruct vocabularies of proto-languages spoken in prehistoric times, such as Proto-Indo-European and Proto-Uralic. This involves comparing vocabularies of languages of the same family (all of which are descended from the same proto-language) for phonologically similar words having the same meanings or very similar meanings. If such words show phonological regularities known as sound correspondences, then they are cognate and, consequently, are descendant forms (reflexes) of words found in their common ancestral language. Knowledge of sound correspondences facilitates the actual reconstruction of words of a proto-language's vocabulary.

PBL applies the comparative approach of historical linguistics to the reconstruction of words for living things. So far, most PBL attention has focused on words for plants. Reconstruction of the phonological shapes of ancient proto-words for species is usually straightforward, with no ambiguity with respect to principles of comparative linguistics. Reconstruction of the referents of proto-words can be straightforward as well, especially when all the

Editor Note: This article is the first in a series we aim to publish on paleobiolinguistics. Because it is a special series, we have allowed an increased number of figures.

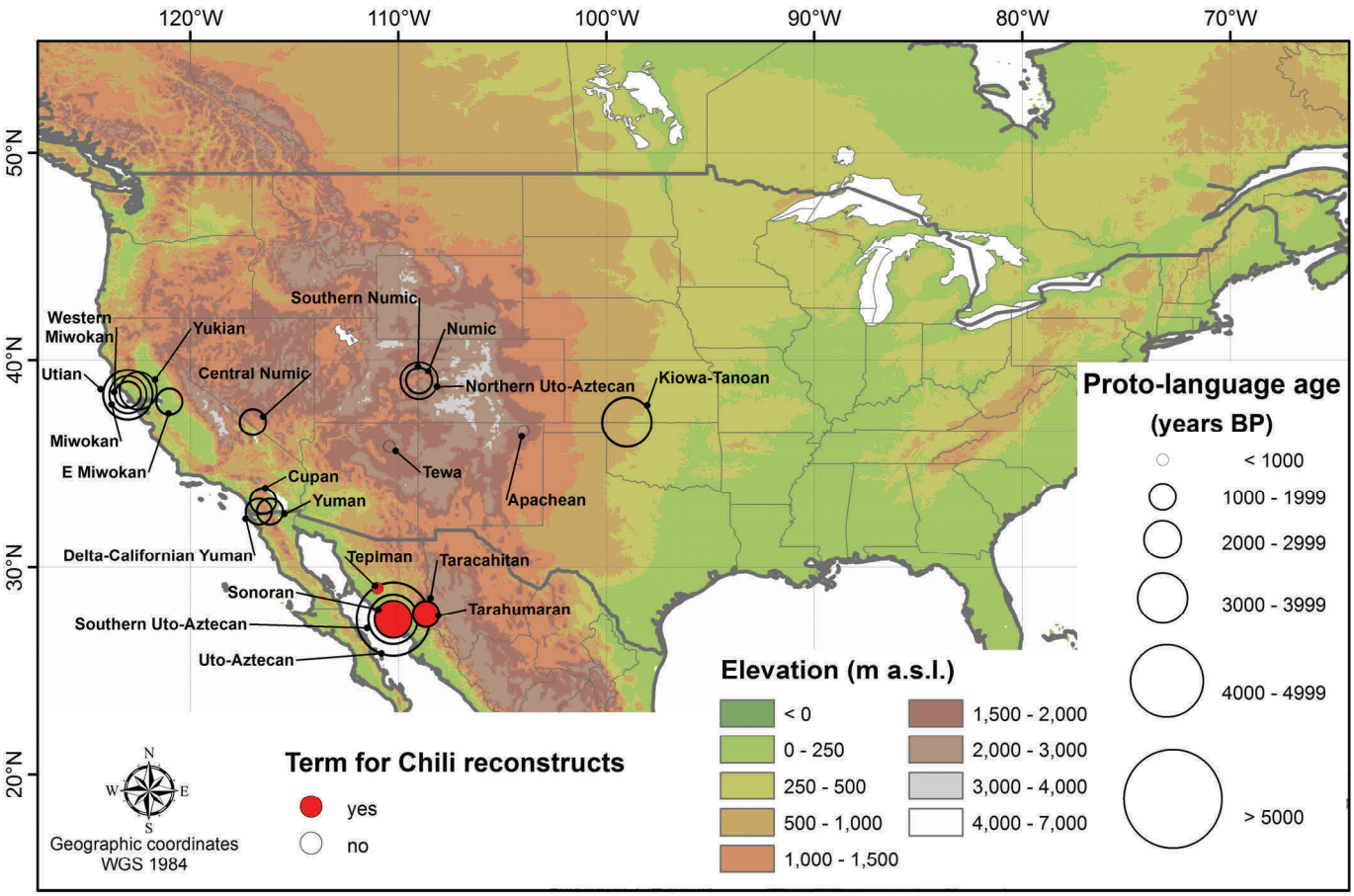

Figure1. Chili pepper-term reconstruction information from Table 1 plotted on map covering North America and Northern Mexico. Centers of circles locate homeland centers of proto-languages (see geographic coordinates of Table 1) and circle size indicates proto-language age (see "years before present" of Table 1), with larger circles indicating older proto-languages and smaller circles, younger ones. Circles are red filled if a chili pepper term reconstructs for a proto-language, and transparent if not.

offspring words designate the same genus or species, such as *Capsicum* spp. or *C. annuum*. When meanings of cognate words differ, even if only slightly, e.g., some refer to *C. annuum*, and others mean 'spicy', there is less certainty that the proto-word actually designated the botanical species itself. In our application of PBL, all reflexes of reconstructed words typically denote the same botanical kind, or, if not, show distributional patterns strongly indicating that the target plant was the proto-term's referent.

An important assumption of PBL is that if a word for a species is found to reconstruct for a proto-language, then that species was of considerable salience to the people who spoke the language. This assumption is strongly supported by research of Berlin et al. (1973) and Balée and Moore (1991) showing that plant words reconstructing respectively for Proto-Tzeltalan (Mayan, Mesoamerica) and Proto-Tupi-Guaraní (South America) designate species that are of robust cultural importance for modern groups speaking offspring languages. On the other hand, plants for which proto-words do not reconstruct are usually not as culturally significant for these groups.

If the botanical kind designated by a proto-word occurs as a domesticated crop in modern times, then it may have been a domesticated crop in prehistoric times. However, there is no guarantee that such was the case. The plant in question could have been, for example, a protected wild species, perhaps one on the verge of being intensely managed, and, ultimately, domesticated. The approach of PBL so far has been to assume confidently only that the species was salient to a prehistoric people, meaning that it was known to most adult speakers of the proto-language.

All of the approximately 30 species of chili

pepper are native to the New World, and five contain domesticated populations. The domesticated taxa include the world's most widely-grown spice, *Capsicum annuum* L., as well as *C. baccatum* L., *C. chinense* Jacq., *C. frutescens* L., and *C. pubescens* Ruiz & Pav. Work during the last half century has established that *C. annuum* was brought into domestication in south-central Mexico, *C. baccatum* in the Andean foothills and adjacent lowlands of Bolivia and extreme southern Peru, *C. chinense* in north-central Amazonia, and *C. pubescens* in the mid-elevation Andes of southern Peru and Bolivia (Eshbaugh 1993; Pickersgill 1984). *Capsicum frutescens* remains a conundrum, since it hybridizes easily with *C. annuum* and *C. chinense*, both of which also hybridize, suggesting the proposal of a *C. annuum-chinense-frutescens* complex (Pickersgill 1984), and that *C. frutescens* may be part of *C. chinense*, rather than a distinct species (Eshbaugh 1993). Nonetheless, *C. frutescens* is always listed as a domesticated Capsicum (Bosland 2008; Perry et al. 2007; Pickersgill 2007), and is believed to have been brought into domestication in Central America (Pickersgill 1984), the Caribbean (Bosland 2008), or southwestern Amazonia (Pickersgill and Heiser 1977).

The oldest macro-botanical remains identified as domesticated *C. annuum* are retrieved from pre-ceramic strata of dry caves in two areas of Mexico, the Tehuacán Valley (Puebla State) and Ocampo (Tamaulipas State), with dates between 9000 and 7000 BP (McClung de Tapia 1992). These dates are produced indirectly through conventional radiocarbon dating of archaeological materials associated with botanical remains, a method yielding less precise dates than those produced by accelerator mass spectrometry (AMS). If eventually subjected to AMS analysis, the Tehuacan and Ocampo remains may prove to be somewhat younger. Nonetheless, they are comparable in great age with indirect dates of *C. chinense* from Guitarrero Cave, in the mid-elevation Peruvian Andes (Pearsall 1992). Given the relative imprecision of indirect radiocarbon dating, Pickersgill (2007) and Perry et al. (2007) conservatively suggest that domesti-

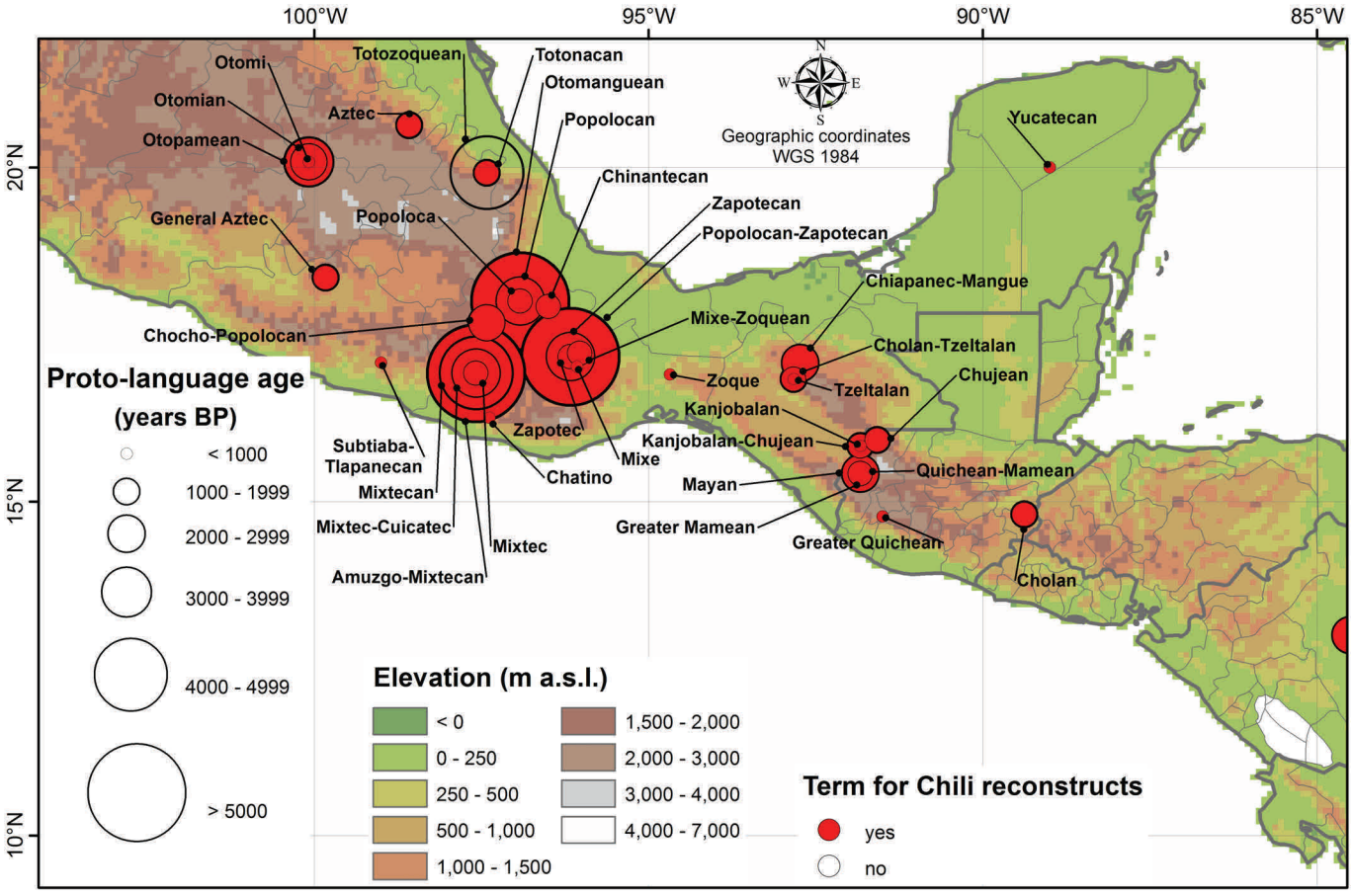

Figure 2. Chili pepper-term reconstruction information from Table 2 plotted on map covering Mesoamerica.

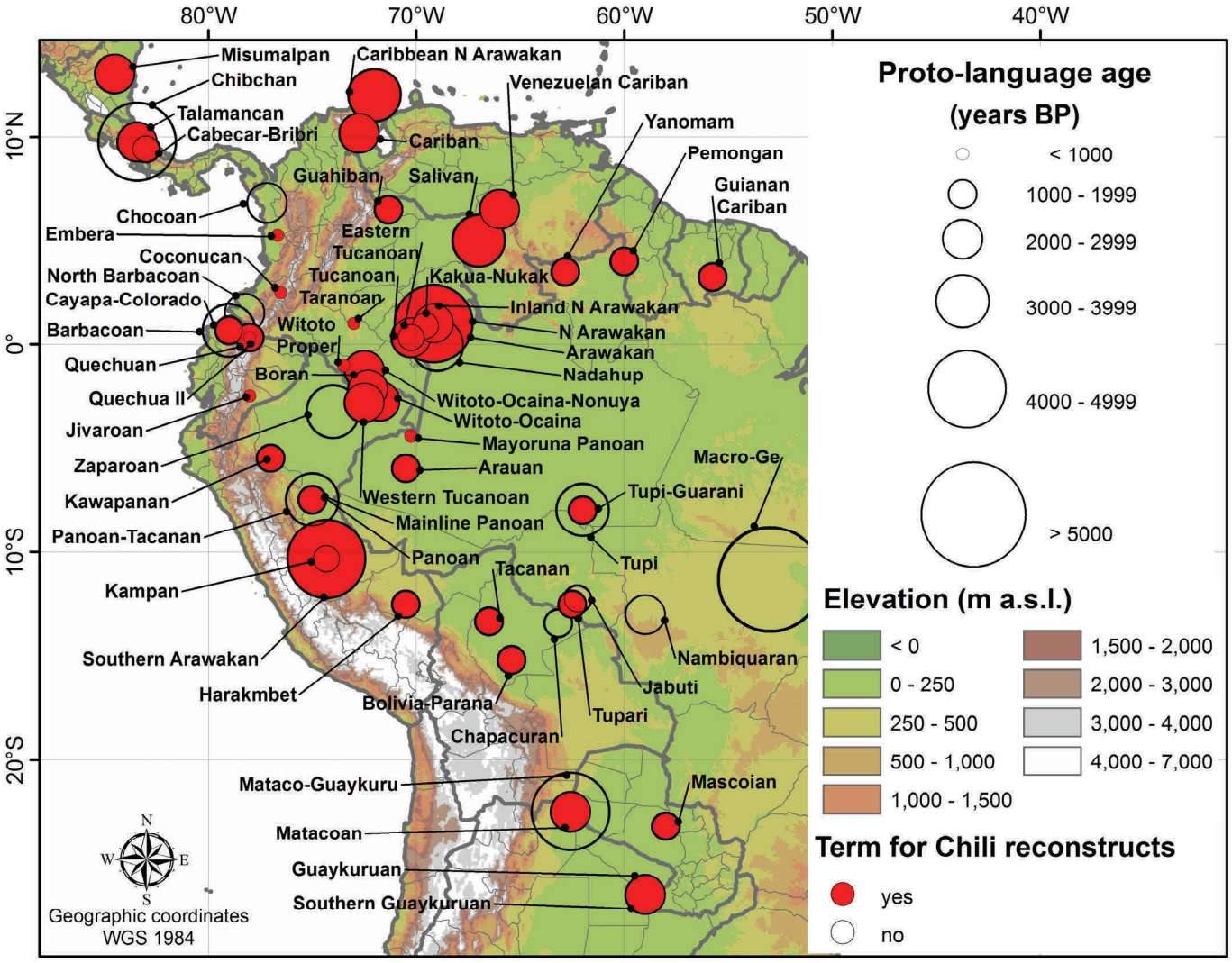

Figure 3. Chili pepper-term reconstruction information from Table 3 plotted on map covering Southern Central America and South America. Area enclosed by yellow square is enlarged in map of Figure 4.

cated *C. annuum* was present by 6000 BP at the latest, and *C. chinense* and *C. baccatum* by about 4000 BP. *Capsicum frutescens* is reported from Huaca Prieta, northern Pacific Peru, between 4000 and 3000 BP (Pearsall 1992), but difficulties in distinguishing *C. frutescens* from *C. chinense* make this assessment problematic. No clearly identified *C. pubescens* are recorded from archaeological sites in South America (Pearsall 1992, 2008).

Tables 1 - 3 present chili pepper-term reconstructions for proto-languages of three major regions of the New World: (1) North America and Northern Mexico (Table 1); (2) Southern Mexico and Northern Central America (henceforth Mesoamerica) (Table 2), and (3) Southern Central America and South America (Table 3). The only New World regions not covered are Arctic and Subarctic parts of Alaska and Canada where chili pepper occurs only as a historical introduction. Chili pepper is also a historical introduction to most groups of North America north of Mexico (accounting for the scant attestation of proto-languages in the region for which chili pepper terms reconstruct [see Figure 1]).

The tables list major proto-languages of the Americas widely regarded by historical linguists as demonstrated. Some major proto-languages are not included because lexical information from daughter languages is not sufficiently available for drawing either positive or negative conclusions about chili pepper-term reconstruction. For each proto-language listed, either a reconstructed word for chili pepper is presented, or NR which stands for "not reconstructa-

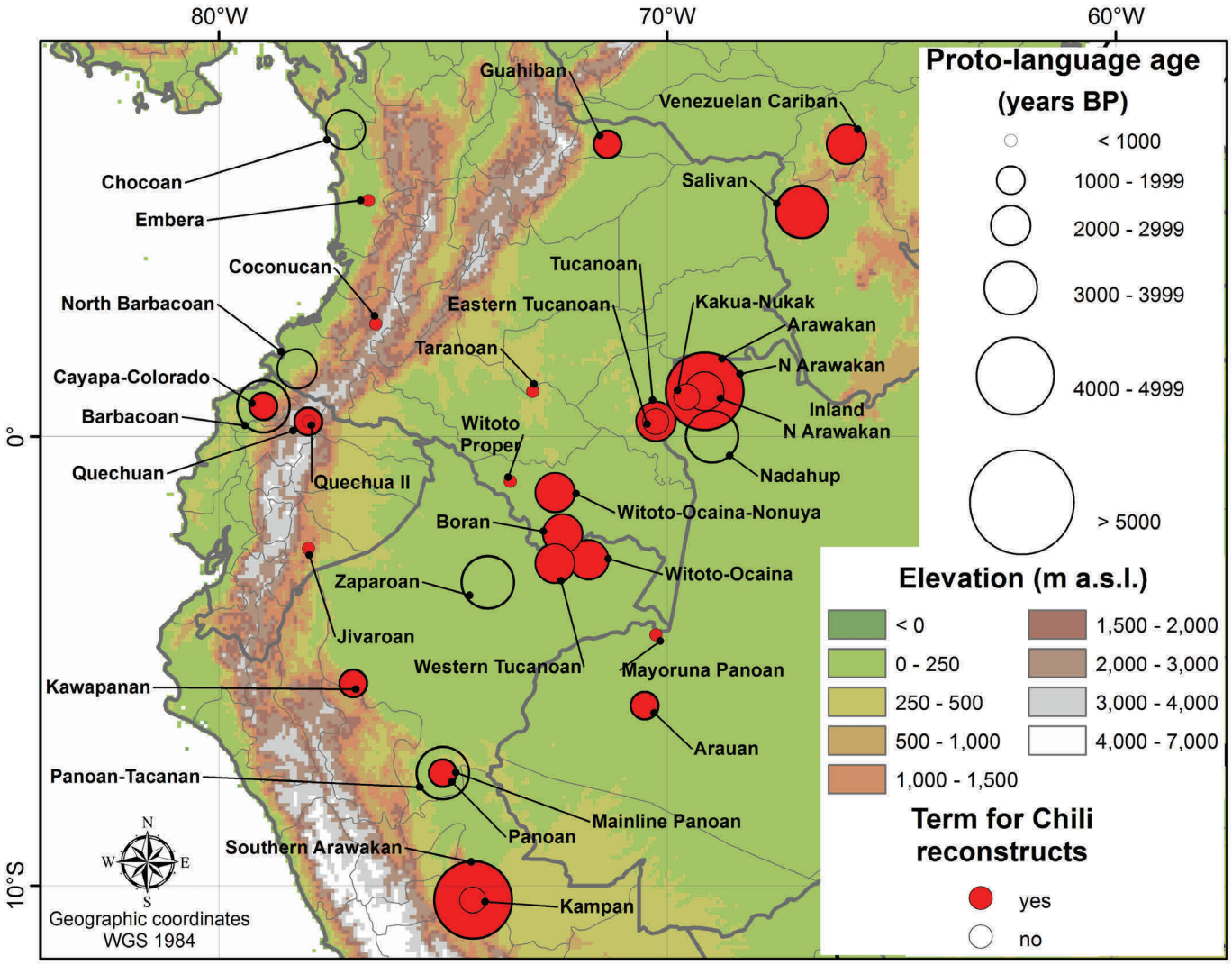

Figure 4. Enlargement of the area of map of Figure 3 enclosed in yellow square.

ble." NR is a designation used when terms for chili pepper are present in all or most languages of a family, but, nonetheless, are not cognate and, hence, do not attest to a chili pepper term in their common ancestral language. NR, then, never indicates non-reconstructibility because of missing data.

Dates for proto-languages presented in the tables are intended to be the latest dates at which these languages were spoken (just before breaking up into daughter languages). These are calculated through use of ASJP (Automated Similarity Judgment Program) chronology, a computational dating approach based on the lexical similarity of languages and a set of 52 calibration dates for proto-language breakups documented through historical, epigraphic, and archaeological records (see Holman et al. 2011). The discrepancies between ASJP estimated dates and the 52 calibration dates are on average 29 percent as large as the estimated dates themselves, a figure that does not differ significantly among language families of the world; also, younger dates tend to be more accurate than older ones (Holman et al. 2011). The 29 percent average difference between an estimated date and its calibration date should be viewed as the estimated date's margin of error. Since an ASJP date indicates the latest date at which a protolanguage was spoken, plausibly any proto-language could have been spoken hundreds of years if not more before its ASJP date.

Occasionally, an ASJP date for a proto-language may be older than a date for its own parent language. For example, Proto-Southern Arawakan (4461 BP) has an ASJP date older than that for Proto-Arawakan (4134 BP). This sometimes occurs in ASJP chronology when a language group's breakup is closely

Table 1. Chili pepper-term reconstruction for proto-languages of North America and Northern Mexico.

Years Before Present	Proto-Language	Proto-Word for Chili Pepper (NR = Not Reconstructable)	Homeland Center Geographic Coordinates	Family Affiliation	Proto-Word Source
4018	Uto-Aztecan	NR	27.5, -110.25	Uto-Aztecan	
3663	Utian	NR	38.33, -123	Utian	
3472	Southern Uto-Aztecan	NR	27.5, -110.25	Uto-Aztecan	
3434	Kiowa-Tanoan	NR	37, -99	Kiowa-Tanoan	
2576	Northern Uto-Aztecan	NR	39, -109	Uto-Aztecan	
2500	Yukian	NR	38.5, -122.5	Yukian	
2400	Sonoran	**ko'okoLi*	27.5, -110.25	Uto-Aztecan	1
2141	Miwokan	NR	38.33, -123	Utian	
1865	Yuman	NR	32.67, -116.17	Yuman	
1827	Taracahitan	**kokori*	27.75, -108.67	Uto-Aztecan	Authors
1737	Numic	NR	39, -109	Uto-Aztecan	
1587	Cupan	NR	33.17, -116.5	Uto-Aztecan	
1573	Southern Numic	NR	39, -109	Uto-Aztecan	
1245	Delta-Californian Yuman	NR	32.67, -116.7	Yuman	
1241	E Miwokan	NR	38, -121	Utian	
1234	Western Miwokan	NR	38.33, -123	Utian	
1213	Tarahumaran	**kokori*	27.75, -108.67	Uto-Aztecan	Authors
1148	Central Numic	NR	37, -117	Uto-Aztecan	
899	Tepiman	**ko'okori*	29, -111	Uto-Aztecan	Authors
718	Apachean	NR	36.58, -104	Athabaskan	
384	Tewa	NR	35.83 -110.42	Kiowa-Tanoan	

Proto-Word Source:
1. Stubbs 2011

followed in time by the breakup of its immediate subgroup. The attested variability of ASJP dates (i.e., margin of error) accounts for this apparent aberrancy (Holman et al. 2011:872).

Possible geographic coordinates for proto-language homeland centers given in the tables are produced through automation using an algorithm for identifying the maximum lexical diversity within a language family (Wichmann et al. 2010). The geographic center of lexical diversity of a family is assumed to correlate with where the family's proto-language was spoken. Tables also give a linguistic family affiliation for each proto-language.

The information reported in Tables 1-3 is plotted in Figures 1, 2 and 3 to give a visual perspective on both the chronological and geographic distributions of reconstructed chili pepper terms. These are maps on which proto-languages are located and their ages indicated by the size of circles locating them, larger circles indicating greater chronological depth than smaller circles. Circles are red filled if a chili pepper term reconstructs for the proto-language, and are transparent if not. The map of Figure 4 is an enlargement of a graphically congested area of the map of Figure 3. Due to methodological considerations, reconstructed words for chili peppers found in New World proto-languages cannot be narrowed referentially to the species level, although informed speculation can sometimes associate some reconstructed names with specific species (see below).

PBL analysis of chili pepper dovetails robustly with archaeological and genetic evidence relating to origins of domesticated *Capsicum annuum*. The oldest

Table 2. Chili pepper-term reconstruction for proto-languages of Mesoamerica (Southern Mexico and Northern Central America).

Years Before Present	Proto-Language	Proto-Word for Chili Pepper (NR = Not Reconstructable)	Homeland Center Geographic Coordinates	Family Affiliation	Proto-Word Source
6591	Otomanguean	*ʔki^{3}	18, -96.92	Otomanguean	1
5498	Popolocan-Zapotecan	*ki	17.17, -96.17	Otomanguean	Authors
5357	Amuzgo-Mixtecan	*nʔsah^{3}	16.92, -97.58	Otomanguean	1
4542	Mixtecan	*(H)yaʔ, Hyah, HΘaʔ^{2}	16.92, -97.58	Otomanguean	1
4274	Totozoquean	NR	19.92, -97.42	Totozoquean	
3654	Otopamean	*(m)ʔi	20.08, -100.08	Otomanguean	2
3149	Zapotecan	*kiiʔnaʔ	17.17, -96.17	Otomanguean	3
3140	Mixtec-Cuicatec	*ya	16.92, -97.58	Otomanguean	Authors
3036	Popolocan	*hña	18, -96.92	Otomanguean	1
2445	Chiapanec-Mangue	*nii-^{n}giʔ	17.07 -92.73	Otomanguean	1
2220	Mayan	*iihk	15.42, -91.83	Mayan	4
2214	Otomian	*ʔi	20.08, -100.08	Otomanguean	5
2209	Chocho-Popolocan	*hna	17.67, -97.42	Otomanguean	Authors
1935	Chinantecan	*ų:^{HL}	17.92, -96.5	Otomanguean	6
1783	Popoloca	*hna	18, -96.92	Otomanguean	Authors
1676	Zapotec	*kiiʔnaʔ	17.17, -96.17	Otomanguean	3
1649	Quichean-Mamean	*iik	15.42, -91.83	Mayan	4
1596	Mixe-Zoquean	*ni:wi	17.22, -96.03	Totozoquean	7
1520	General Aztec	*čiil-	18.35, -99.83	Uto-Aztecan	8
1492	Greater Mamean	*iik	15.42, -91.83	Mayan	4
1437	Mixtec	*ya'a	16.92, -97.58	Otomanguean	Authors
1435	Totonacan	*pi'n	19.92, -97.42	Totozoquean	9
1432	Cholan-Tzeltalan	*iihch	16.83, -92.83	Mayan	4
1225	Kanjobalan-Chujean	*iik	15.83, -91.83	Mayan	4
1198	Corachol	*ku'ukuri	22.17, -104.83	Uto-Aztecan	Authors
1186	Aztec	*čiil-	20.63, -98.58	Uto-Aztecan	Authors
1148	Cholan	*iich	14.81, -89.38	Mayan	4
1058	Chujean	*ich	15.92, -91.58	Mayan	4
997	Chatino	*kìnáʔ	16.25, -97.38	Otomanguean	3
981	Greater Quichean	*iik	14.78, -91.5	Mayan	4
948	Subtiaba-Tlapanecan	*dutų	17.08, -99	Otomanguean	Authors
900	Mixe	*ni:wi	17.02, -96.07	Totozoquean	7
802	Kanjobalan	*iik	15.83, -91.83	Mayan	4
790	Yucatecan	*iihk	20, -89	Mayan	4
787	Zoque	*niwi	16.9, -94.68	Totozoquean	7
741	Otomi	*ʔi	20.08, -100.08	Otomanguean	10
511	Tzeltalan	*ich	16.83, -92.83	Mayan	4

Proto-Word Source:

1. Rensch 1976
2. Bartholomew 1965
3. Campbell 2013
4. Brown and Wichmann 2004
5. Newman and Weitlaner 1950b
6. Rensch 1989
7. Wichmann 1995
8. Campbell and Langacker 1978
9. Brown et al. 2011
10. Newman and Weitlander 1950a

Table 3. Chili pepper-term reconstruction for proto-languages of Southern Central America and South America.

Years Before Present	Proto-Language	Proto-Word for Chili Pepper (NR = Not Reconstructable)	Homeland Center Geographic Coordinates	Family Affiliation	Proto-Word Source
7266	Macro-Ge	NR	-11.3, -53	Macro-Ge	
4701	Mataco-Guaykuru	NR	-22.5, -62.58	Mataco-Guaykuru	
4461	Southern Arawakan	**tsiti*	-10.33, -74.33	Arawakan	Authors
4400	Chibchan	NR	9.75, -83.42	Chibchan	
4134	Arawakan	**ačɨdɨ*	1, -69.17	Arawakan	1
4085	N Arawakan	**ači*	1, -69.17	Arawakan	Authors
3943	Panoan-Tacanan	NR	-7.5, -75	Panoan-Tacanan	
3585	Tupi	NR	-8, -62	Tupi	
3518	Caribbean N Arawakan	**(h)ači*	12, -72	Arawakan	Authors
3310	Salivan	**tare'te*	5, -67	Salivan	Authors
3178	Zaparoan	NR	-3.25, -74	Zaparoan	
3124	Nadahup	NR	0, -69	Nadahup	
3041	Barbacoan	NR	0.67, -79	Barbacoan	
2927	Witoto-Ocaina	**hiʔpí-*	-2.75, -71.75	Witoto-Ocaina-Nonuya	2
2909	Guaykuruan	NR	-26.5, -59	Mataco-Guaykuru	
2857	Witoto-Ocaina-Nonuya	**(hi)pi-*	-1.25, -72.5	Witoto-Ocaina-Nonuya	3
2807	Nambiquaran	NR	-13, -59	Nambiquaran	
2774	Misumalpan	**kuma*	13, -84.5	Misumalpan	4
2731	Talamancan	**yibah*	9.75, -83.42	Chibchan	Authors
2699	Tucanoan	**p'ia*	0.33, -70.25	Tucanoan	5
2593	Inland N Arawakan	**(h)a(ʔ)(n)tsi*	1, -69.17	Arawakan	6
2503	Venezuelan Cariban	**pëmëi*	6.5, -66	Cariban	Authors
2433	Southern Guaykuruan	**kodai*	-26.5, -59	Mataco-Guaykuru	Authors
2414	North Barbacoan	NR	1.5, -78.25	Barbacoan	
2412	Cariban	**pëmëi*	10.17, -72.75	Cariban	7
2404	Matacoan	**pA-ahn-Ajn*	-22.5, -62.58	Mataco-Guaykuru	8
2271	Boran	**dĩĩ-ʔoï*	-2.17, -72.33	Boran	2
2258	Chocoan	NR	6.83, -77.17	Chocoan	
2156	Western Tucanoan	**p'ia*	-2.83, -72.5	Tucanoan	Authors
1931	Chapacuran	NR	-13.42, -63.17	Chapacuran	
1850	Tupari	**kõy*	-12.5, -62.5	Tupi	9
1780	Mascoian	**yam-natikhik*	-23.2, -58	Mascoian	Authors
1764	Arauan	**kashi'i*	-6, -70.5	Arauan	10
1717	Quechuan	**uchu*	0.33, -78	Quechuan	11
1672	Panoan	NR	-7.5, -75	Panoan-Tacanan	
1647	Bolivia-Parana	**ičeti*	-15.17, -65.42	Arawakan	Authors
1634	Mainline Panoan	**yoči*	-7.5, -75	Panoan-Tacanan	12

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Years Before Present	Proto-Language	Proto-Word for Chili Pepper (NR = Not Reconstructable)	Homeland Center Geographic Coordinates	Family Affiliation	Proto-Word Source
1607	Jabuti	NR	-12.25, -62.25	Macro-Ge	
1590	Tacanan	**biju*	-13.33, -66.5	Panoan-Tacanan	13
1569	Harakmbet	**ɨg*	-12.5, -70.5	Harakmbet	Authors
1550	Tupi-Guarani	**kɨʔɨj*	-8, -62	Tupi	14
1519	Kampan	**tsitikana*	-10.33, -74.33	Arawakan	Authors
1419	Cayapa-Colorado	**tʸuN*	0.67, -79	Barbacoan	15
1402	Guianan Cariban	**pëmëi, *asï(sï)*	3.25, -55.75	Cariban	Authors
1395	Cabecar-Bribri	**dipa*	9.42, -83	Chibchan	Authors
1335	Kakua-Nukak	**tubni*	0.88, -69.56	Kakua-Nukak	Authors
1319	Yanomam	**praki*	3.5, -62.83	Yanomam	Authors
1291	Guahiban	**noN-hi*	6.5, -71.33	Guahiban	16
1241	Eastern Tucanoan	**bia*	0.33, -70.25	Tucanoan	Authors
1185	Kawapanan	**nu(ʔ)kaʔ*	-5.5, -77	Kawapanan	17
1169	Pemongan	**pëmëi*	4, -60	Cariban	Authors
992	Taranoan	**pëmëi*	1, -73	Cariban	18
974	Quechua II	**uchu*	0.33, -78	Quechuan	Authors
875	Embera	**pʰi'da*	5.25, -76.66	Chocoan	Authors
678	Jivaroan	**ximʸa*	-2.5, -78	Jivaroan	Authors
419	Coconucan	**kɨ'rɨ*	2.5, -76.5	Barbacoan	Authors
414	Witoto Proper	**hipi-*	-1, -73.5	Witoto-Ocaina-Nonuya	2
389	Mayoruna Panoan	**sia*	-4.42, -70.25	Panoan-Tacanan	Authors

Proto-Word Source:

1. Payne 1991
2. Aschmann 1993
3. Echeverri and Seifart 2011
4. Constenla-Umaña 1987
5. Chacon 2012
6. Ramirez 2001
7. Sergio Meira, per. com.
8. Najlis 1984
9. Moore and Galucio 1994
10. Dixon 2004
11. Willem Adelaar, per. com.
12. Shell 2008
13. Girard 1971
14. Mello 2000
15. Moore 1962
16. Christian and Matteson 1972
17. Pilar Valenzuela, per. com.
18. Meira 2000

reconstructed term for Capsicum is found for Proto-Otomanguean (6592 BP). This language's homeland is in south-central Mexico (Figure 2), the area in which *C. annuum* was domesticated at the latest by 6000 years ago. Proto-Southern Arawakan shows the oldest date for an ancestral language of South America (Figures 3 and 4) for which a chili-pepper term reconstructs (4461 BP). The location and chronology of this proto-language suggest a relationship with the domestication of *C. baccatum* in the Andean foothills and adjacent lowlands of Bolivia and extreme southern Peru by 4000 BP at the latest. The location and age of Proto-Arawakan suggests a relationship with *C. chinense*, which is hypothesized to have been domesticated in north-central Amazonia by 4000 BP at the latest.

Proto-languages for which chili pepper terms reconstruct are found broadly distributed through Mesoamerica and South America, reflecting the likely independent domestication of Capsicum in these two major regions. The early dates of these ancestral languages indicate a human interest in chili peppers in most parts of Latin America that preceded widespread development of a village-farming way of life by at least a millennium.

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