COCA AND COCAINE

Effects on People and Policy in Latin America

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Editors

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COCA CHEWING AND THE BOTANICAL ORIGINS OF COCA (ERYTHROXYLUM SPP.) IN SOUTH AMERICA

Timothy Plowman

The coca leaf has played an important role in the lives of South American Indians for thousands of years. Its use as a masticatory persists today in many parts of the Andes, from northern Colombia, south to Bolivia and Argentina, and in the western part of the Amazon Basin. Coca leaf is used as a mild stimulant and as sustenance for working under harsh environmental conditions by both Indians and mestizos alike. It also serves as a universal and effective household remedy for a wide range of medical complaints. Traditionally, coca also plays a crucial symbolic and religious role in Andean society. The unifying and stabilizing effects of coca chewing on Andean culture contrasts markedly with the disruptive and convoluted phenomenon of cocaine use in Western societies. Because all cocaine entering world markets is derived from coca leaves produced in South America, the staggering increase in demand for cocaine for recreational use has had a devastating impact on South American economies, politics and, most tragically, on indigenous cultures.

The widespread intranasal use of cocaine hydrochloride or smoking of cocaine base produce quite different psychological and pharmacological experiences than the traditional chewing of coca leaves. The differences between taking concentrated cocaine and chewing coca have been pointed out repeatedly by earlier workers (Mortimer 1901; Weil 1975; Grinspoon and Bakalar 1976; Antonil 1978; inter alia). Yet many people still equate the use of coca with that of cocaine and fail to comprehend either the pharmacological or cultural differences between these two related, though unique, substances. In Western society, the public is well aware of both the pleasurable and deleterious effects of cocaine because of extensive news coverage of the cocaine "phenomenon" of recent years. Few people, however, are aware of the beneficial effects of coca chewing, of the importance of the use of coca in Andean life, or of the origin and evolution of the coca plant.

The purposes of this paper are twofold: first, to describe the process of coca chewing, the effects of coca and how it is used traditionally; and second, to discuss the botanical sources, antiquity, geographic distribution and putative evolutionary history of coca. Most of the information presented here has been published elsewhere and recently summarized (Plowman 1984a, 1984b). Readers are directed to these articles for more detailed information and references.

Coca Chewing

Coca leaves are chewed in a relatively uniform manner throughout their area of use with only minor variations. Coca is always dried before use; this facilitates the rapid release of the chemical constituents from the leaves during chewing. The dried leaves are placed in the mouth one or a few at a time and slowly moistened with saliva. This act is frequently accompanied by traditional rituals and etiquette (Allen 1981). Almost immediately, a rich, green juice issues from the leaves, and they become soft and pliable. The leaves are then moved about in the mouth with the tongue, rolled into a ball or quid and pushed into one cheek. Coca is never really chewed, but rather the moistened quid of leaves is sucked upon to extract the juices, which slowly trickle into the stomach. In South America, a number of words are used specifically to denote coca chewing: *mambear* (Colombia); *chacchar, acullicar, pijchear* (Peru, Bolivia); *coquear* and *mascar* (general).

The juice that emanates from the quid is distinctive in flavor, which depends upon the variety of coca. Generally, coca has a grassy or hay-like taste, with a hint of wintergreen in Trujillo and Colombian coca. During the earliest stages of chewing, all coca varieties are distinctly bitter because of the presence of alkaloids, primarily cocaine. This bitterness is counteracted by the addition of an alkali substance, such as powdered lime or ashes – or even sodium bicarbonate among nonnative chewers. The powdered lime is traditionally carried in a small bottle gourd and added to the quid with a slender dipper or stick. The alkali not only "sweetens" the chew but also noticeably potentiates its effects, both in numbing the cheeks and tongue (through the anesthetic effect of cocaine) and by increasing the stimulating effect. Additional doses of alkali periodically are added to the quid to maintain its effect on the chew; more leaves may be added until the quid reaches an optimal size for the chewer.

The amount of time the coca quid is kept in the mouth varies, depending on the individual user, from about 30 to 90 minutes, after which the quid is spat out. The amount of coca chewed also varies according to individual taste and availability, ranging generally from 25 to 75 grams of leaves per day with an average of about 50 grams (Plowman 1984a).

All varieties of cultivated coca contain the alkaloid cocaine, by weight generally less than one percent of the dry leaf; Amazonian coca contains less than 0.5 percent. In addition, all varieties contain the secondary alkaloid cinnamoylcocaine (Plowman and River 1983). Although this alkaloid may be present in substantial amounts, it is not known to have any pharmacological effects (Novak et al. 1984). In addition to alkaloids, coca leaves may contain significant amounts of wintergreen oil, methyl salicylate, which gives a distinctive flavor to the leaves. Recent studies have also isolated several flavonoid compounds (Bohm et al. 1982). These are useful in chemotaxonomy but have no known pharmacological effects.

An important group of constituents in coca – nutrients – has been largely overlooked or ignored. During the 1970s a number of studies demonstrated that coca leaves contain impressive amounts of vitamins and

Contemporary coca chewer inserting powdered lime into coca quid, Balsas, Río Marañon, Amazonas, Peru. ©Timothy Plowman

minerals (Machado 1972; Duke et al. 1975; Carter et al. 1980). In one study (Duke et al. 1975) the amounts of 15 nutrients in Bolivian coca leaves were compared to averages of these nutrients present in 50 Latin American foods. Coca was found to be higher in calories, protein, carbohydrates, fibers, calcium, phosphorus, iron, vitamin A and riboflavin. Based on these data, 100 grams of Bolivian coca would more than satisfy the Recommended Dietary Allowance for reference man and woman in calcium, iron, phosphorus, vitamin A and riboflavin. These data contradict earlier claims that coca chewing results in malnutrition (cf. Saenz 1941; Gutierrez-Noriega and Zapata Ortiz 1948; Zapata Ortiz 1970).

The primary effect of chewing coca is a mild stimulation of the central nervous system resulting from the assimilation of cocaine from the leaves (Holmstedt et al. 1979). This stimulation gives a sense of increased energy and strength, a suppression of the sensation of fatigue, an elevation of mood or mild euphoria and a sense of well-being and contentment. Coca also produces a temporary suppression of appetite, but it is never used in

place of food (Burchard 1975). Owing to the local anesthetic properties of cocaine, coca chewers experience a pronounced numbing sensation on the cheeks and tongue. Some workers (Montesinos 1965; Burchard 1975) have suggested that the ecgonine (an alkaloid) derivatives of cocaine may play a role in the combined effects of coca chewing, but their theories have yet to be confirmed with controlled experiments.

There is no evidence that coca chewing results in tolerance or physiological dependence, or any acute or chronic deleterious effects (Weil 1975; Grinspoon and Bakalar 1976; Carter et al. 1980). Ironically, although there has been a massive research effort on the effects of cocaine, no modern pharmacological studies of coca chewing in native coca chewers have been conducted to date. Even though cocaine is the principal and most powerful constituent of coca leaves, the complex effects of chewing the leaves cannot be equated with the comparatively straightforward effects of cocaine.

Whether in the high Andean *Altiplano* (high plateau region) or in the Amazonian lowlands, the principal use of coca is for work (Burchard 1975; Carter et al. 1980; Plowman 1981, 1984a). Workers will take several breaks during the daily work schedule to rest and chew coca, not unlike the coffee break of Western society. Coca chewers maintain that coca gives them more vigor and strength and assuages feelings of hunger, thirst, cold and fatigue. Coca is chewed by rural people in all kinds of professions that require physical work, especially by farmers, herders and miners in the highlands and by farmers, fishermen and hunters in the lowlands. Coca is especially highly regarded for making long journeys on foot whether in the high Andes or Amazonian forests (Mortimer 1901; Martin 1970; Plowman 1981).

The second most important use of coca is as a medicine, and this use is inextricable from the Indians' belief that coca is a protector and preserver of health. It is significant that many South Americans, Indians and non-Indians, who do not regularly chew coca as a stimulant will cultivate the plant and use the leaves medicinally. As an internal medicine, coca is both taken as an infusion and chewed as a quid. Probably the most important medicinal use of coca is for disorders of the gastrointestinal tract. It is the remedy of choice for dysentery, stomachaches, indigestion, cramps, diarrhea, stomach ulcers and other painful conditions (Martin 1970; Fabrega and Manning 1972; Hulshof 1978; Carter et al. 1980, 1981; Weil 1981; Grinspoon and Bakalar 1981). Coca is also the most important remedy for treating symptoms of altitude sickness or *soroche*, which include nausea, dizziness, cramps and severe headaches. Coca is also commonly used for toothaches, rheumatism, hangovers and numerous other ailments, taken either internally or applied as a plaster or poultice.

Since the turn of the century, the importance of coca leaf as a medicine has been largely ignored by Western scientists, who identified coca leaf with cocaine and preferred to experiment with the pure, isolated compound. As a result, coca leaves completely disappeared as a pharmaceutical product and no longer were available for investigation in the United States and Europe.

Recently, coca is being restudied for possible applications in modern medicine. Weil (1981) has recommended that coca be studied for several therapeutic applications, including: (1) for painful and spasmodic conditions of the entire gastrointestinal tract; (2) as a substitute stimulant for coffee in persons who suffer gastrointestinal problems from its use or who are overly dependent on caffeine; (3) as a fast-acting antidepressant and mood elevator without toxic side effects; (4) as a treatment for acute motion sickness; (5) as an adjunctive therapy in programs of weight reduction and physical fitness; (6) as a symptomatic treatment of toothache and sores in the mouth; (7) as a substitute stimulant to wean addicted users of amphetamines and cocaine which are more dangerous and have higher abuse potential; and (8) as a tonic and normalizer of body functions.

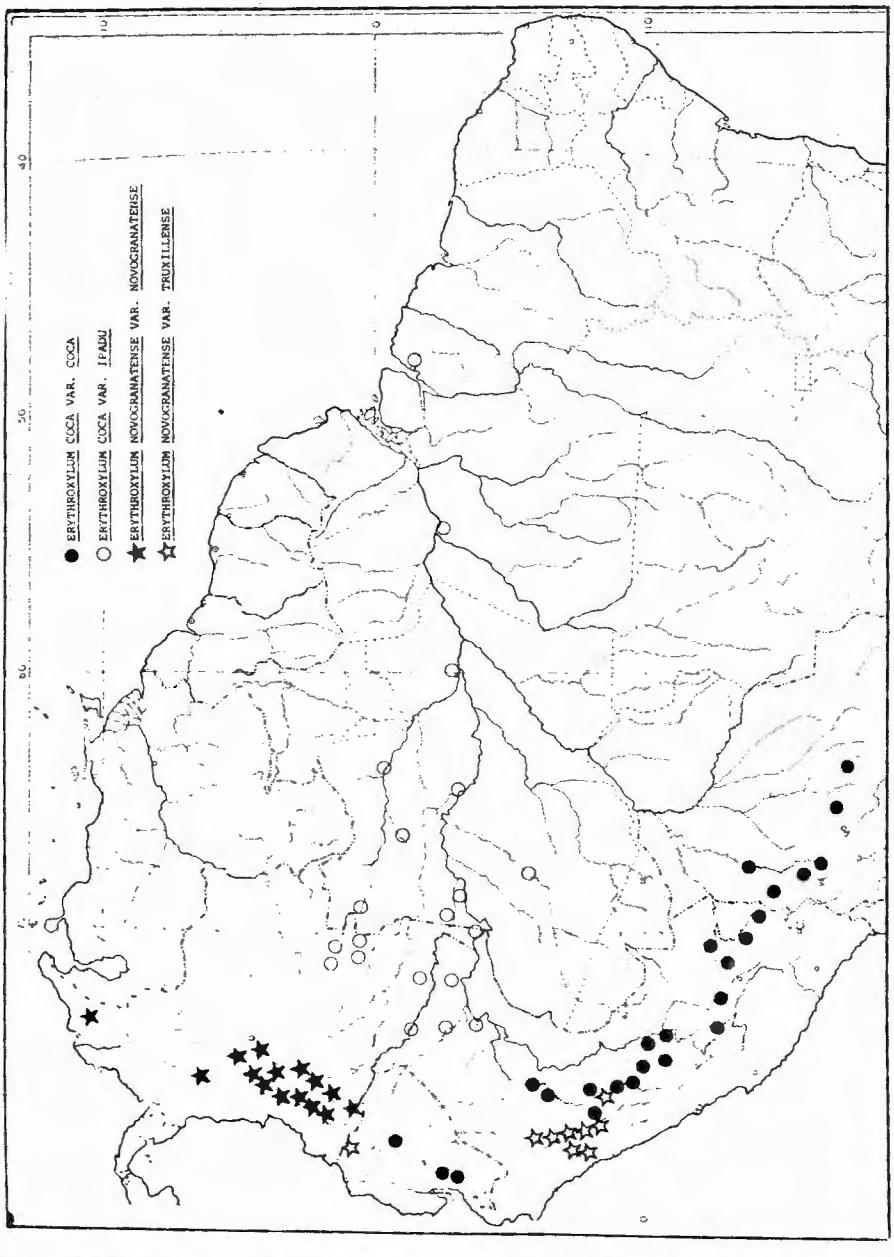
The Botany of Coca

The origin and nature of the coca plant have long been subjects of controversy and uncertainty in botanical, medical, pharmaceutical and anthropological circles (Plowman 1979a, 1982, 1984a, 1984b). Until recently, many scholars underestimated or completely overlooked the importance of the existence of distinct varieties of coca. Although geographical, ecological and morphological differences in coca varieties were recorded as early as the sixteenth century, their significance was not recognized until the 1970s (Rostworowski 1973; Antonil 1978; Plowman 1979a). Not until coca leaf became an important pharmaceutical product in the late nineteenth century did the botanical origins and varieties of coca become the subject of scientific inquiry (Plowman 1982).

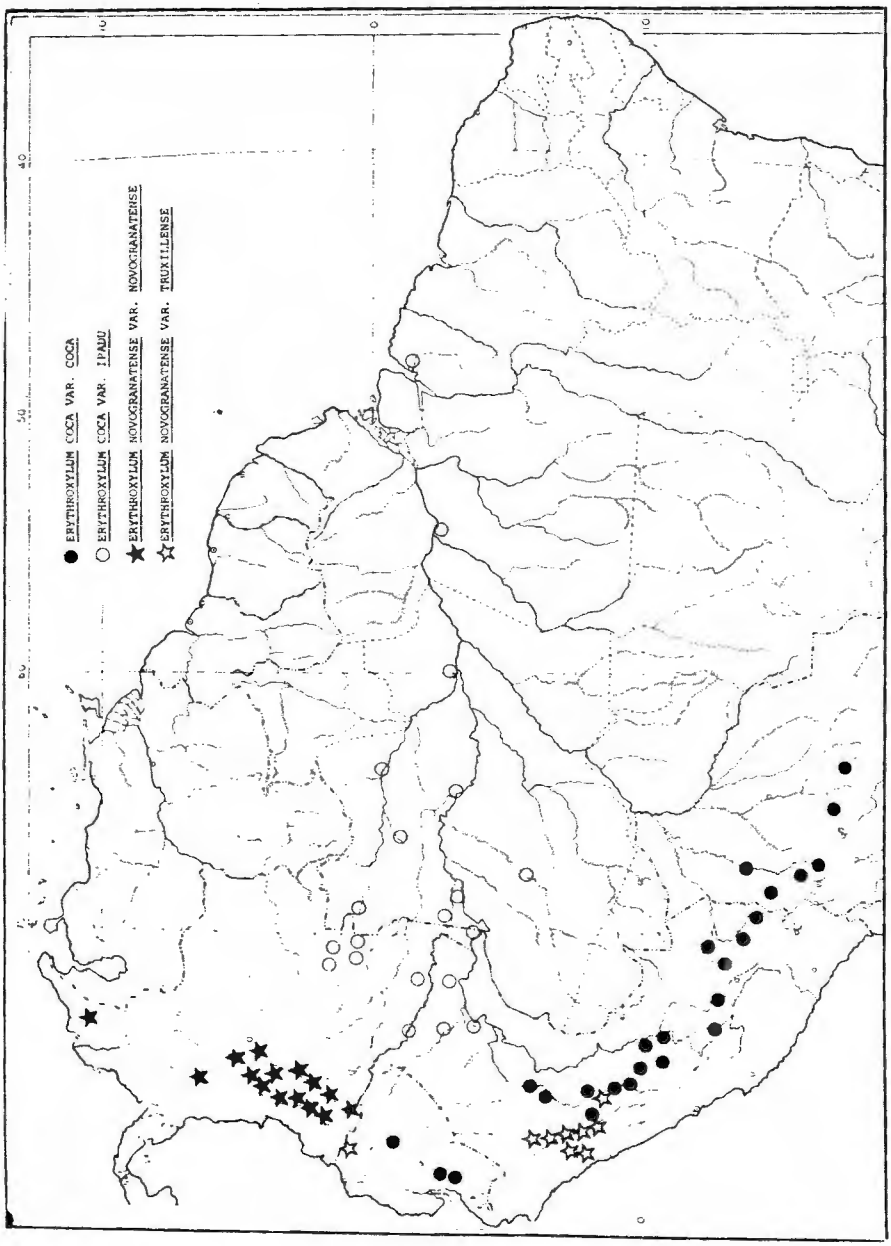
Most anthropologists and archeologists in the past embraced a monotypic view of coca, largely because of their unfamiliarity with botanical works. As a result, their interpretations of the early history of coca in South American cultures were often simplistic, misguided or erroneous. It is only through recent collaborative efforts that a thorough, multidisciplinary understanding of coca is now possible.

The coca shrub belongs to the genus *Erythroxylum* in the tropical family Erythroxylaceae. *Erythroxylum* includes about 250 species, most of which occur in the New World tropics. Many species are employed in folk medicine (Hegnauer 1981), but it is only in tropical America where *Erythroxylum* leaves are chewed extensively as a stimulant and where the plants attain major cultural importance (Mayer 1978; Antonil 1978; Plowman 1984a, 1984b).

All cultivated coca is derived from two closely related South American species: *Erythroxylum coca* Lam. and *E. novogranatense* (Morris) Hieron. Whereas certain wild neotropical species of *Erythroxylum* may be employed locally as medicines, all discussions of "coca" should be confined to these two cultivated species. Until the mid-1970s, only one species of "coca" — *Erythroxylum coca* — was generally recognized (Mortimer 1901; Hegnauer and Fikenscher 1960; Martin 1970). However, evidence resulting from intense field and laboratory studies has accumulated during the past



Present Distribution of the Four Varieties of Cultivated Coca (*Erythroxylum* spp.)
Based on Herbarium Collections



Present Distribution of the Four Varieties of Cultivated Coca (*Erythroxylum* spp.)
Based on Herbarium Collections

decade and demonstrates incontrovertibly that two distinct species of coca should be recognized (Plowman 1979a; Rury 1981, 1982; Bohm et al. 1982; Plowman and Rivier 1983; Plowman 1984a).

Each of the two species of cultivated coca has one distinct variety, designated *E. coca* var. *ipadu* Plowman and *E. novogranatense* var. *truxillense* (Rusby) Plowman, respectively. The four cultivated cocas of South America are thus treated as follows: *Erythroxylum coca* var. *coca*, *E. coca* var. *ipadu*, *E. novogranatense* var. *novogranatense* and *E. novogranatense* var. *truxillense*.

All four cultivated cocas were domesticated in pre-Columbian times and are still employed by native coca chewers in South America. Each of them was known by a different native name before the Spanish popularized the now widespread term "coca." All the cultivated cocas contain the alkaloid cocaine, although they are now known to differ appreciably in the content of minor alkaloids and other chemical constituents (Bohm et al. 1982; Plowman and Rivier 1983). Additional important differences among the four varieties are found in their stem and leaf anatomy, ecology, geographical distribution, and breeding relationships, as well as in the methods of their cultivation and preparation for chewing. These differences reflect intensive human selection over thousands of years for specific traits and for successful cultivation in a wide variety of habitats.

The four varieties of cultivated coca are more closely related to each other than to any other species of *Erythroxylum*, although certain wild species clearly belong to the same species group and some also contain cocaine (Plowman and Rivier 1983). Superficially the cultivated cocas are very similar morphologically, which in part explains earlier confusion in the identification of coca, especially by nonspecialists (Plowman 1979a, 1982). The varieties usually can be distinguished using combinations of characters including the branching habit, bark, leaves, stipules, flowers and fruits. In most cases, isolated coca leaves can now be identified to species if not to variety, especially if the provenance of the samples is known.

Recent studies have provided additional new characteristics that permit the accurate identification of coca leaves, including archeological specimens. These studies focus on leaf anatomy (Rury 1981, 1982; Rury and Plowman 1983; Plowman and Rivier 1983), reproductive biology and breeding relationships (Ganders 1979; Bohm et al. 1982), and ecology and geographical distribution (Plowman 1979a, 1979b, 1981, 1984a, 1984b). As a result of these investigations, the taxonomic and evolutionary relationships among the four cultivated cocas are now fairly well understood.

Erythroxylum Coca var. Coca, Huánuco or Bolivian Coca

The species *Erythroxylum coca* includes the wide-ranging and economically important Andean variety *E. coca* var. *coca* and a geographically restricted Amazonian variety *E. coca* var. *ipadu*. Var. *coca* is often referred to as "Bolivian" or "Huánuco" coca, but neither of these

Huánuco coca (*Erythroxylum coca* var. *coca*) plantation at Naranjilla near Tingo María, Huánuco, Peru. ©Timothy Plowman

common names conveys the extensive geographic range of the variety. For convenience, I will refer to this variety as "Huánuco coca."

Huánuco coca is a shrub one to three m tall and grows mainly between 500 and 1,500 m elevation but may reach 2,000 m in some areas. It is cultivated in regions of moist tropical forest along the eastern slopes of the Andes and in the wetter inter-Andean valleys, in the ecological zone known generally as *montaña*. Because it has a fairly limited ecological range, Huánuco coca is little known outside its original area in South America. It is this variety that is the principal commercial source of coca leaves and of most of the world's cocaine supply.

The leaves of Huánuco coca vary appreciably in their cocaine content. Chemical analyses of dried leaves from many localities in Peru and Bolivia varied from 0.23 percent to 0.93 percent cocaine, with an average of 0.63 percent. The most potent leaf came from Chinchao in Huánuco, a locality near the upper limits of coca cultivation; this supports a long-held view that coca from higher elevations contains higher concentrations of cocaine (Plowman and Rivier 1983).

Geographically, Huánuco coca extends from Ecuador south to Bolivia. Only in Ecuador, where suitable moist forest habitats occur on both sides of the Andes, does this variety reach the Pacific slope. It is unknown in Colombia or in the Amazonian lowlands.

Throughout its range, Huánuco coca is found as wild-growing or feral individuals in the understory of primary or secondary forests, both nearby

and far from areas of present coca cultivation. It is well adapted to the montaña habitat, where it appears to be a natural component of the forest understory, occurring sympatrically with several wild species of *Erythroxylum*.

It is usually impossible to distinguish between truly wild-growing individuals of Huánuco coca and plants that have been dispersed from nearby plantations or that persist after plantations are abandoned. There are apparently no barriers to gene flow between wild and cultivated populations, which freely interbreed when growing in proximity. The small, red fruits are eagerly eaten by birds, which disseminate the seeds throughout the montaña zone. There are no essential structural differences between wild-growing and cultivated plants of *E. coca* var. *coca*, and this variety remains largely unaltered morphologically, genetically or physiologically through domestication. Throughout the range of Huánuco coca one finds local variants, the result of local selection in a particular isolated valley or microclimate. Although these variants often bear vernacular names, and several may be recognized in a particular place, they are minor forms that carry no taxonomic significance. However, these forms or cultivars represent the long history of cultivation and local selection of Huánuco coca throughout the eastern Andes. Unfortunately, no detailed studies exist that document these local variants.

Erythroxylum coca var. *coca* is now thought to be a naturally occurring, wild species of the montaña, from which the other three cocas ultimately were derived as cultigens through human selection. Originally *E. coca* var. *coca* had a more limited distribution as a wild species, possibly in eastern Peru in the area centering on the Huallaga Valley, where wild-growing Huánuco coca is frequently encountered today. Subsequent range extensions northward to Ecuador and southward to Bolivia probably occurred through man's cultivation.

Huánuco coca is cultivated in small to large plantations on steep mountain slopes and in valley bottoms along the eastern flanks of the Andes. This is an area of generally high rainfall and fertile soils, covered naturally by moist, tropical forest. On steep slopes the shrubs are planted in neat rows on carefully-prepared terraces. Coca terraces are especially evident in the ancient coca-growing districts of Cuzco, Peru and in the Bolivian Yungas. In newer areas of expanding coca production, such as the Huallaga Valley in Peru and the Chapare in Bolivia, terracing is less important and the shrubs are merely planted in rows on newly cleared hillsides (Plowman 1984a).

Huánuco coca is always grown from seeds, which are germinated in special nurseries or planted directly into the field under shade of manioc (Plowman 1984a). Once established, a plantation of Huánuco coca will yield its first harvest in one to two years and reach maximum productivity in about five years. Well-maintained plantations may remain productive for up to 40 years, although productivity decreases after 10-15 years. Huánuco coca is harvested three to four times per year; each shrub is stripped of all or

Terraced fields of Huánuco coca (*Erythroxylum coca* var. *coca*) on steep hillside in the Bolivian Yungas, along road from Coroico to Ayapata. ©Timothy Plowman

A man harvests Huánuco coca (*Erythroxylum coca* var. *coca*) at Maranura hacienda in Cuzco, Peru. ©Timothy Plowman

most of its leaves during each harvest. In areas such as Tingo María, where owners of large plantations employ modern agricultural methods, up to six harvests per year are possible.

Production yields of Huánuco coca vary from region to region. In Peru, yields in 1971 varied from 410 kg/hectare (Madre de Dios) to 1,200 kg/hectare (San Martín) with a national average of 810 kg/hectare (Daneri Perez 1974). In Bolivia, 1972 yields in the traditional coca districts of the Yungas averaged only 260 kg/hectare, whereas the Chapare districts averaged 851 kg/hectare (South 1977).

Erythroxylum Coca var. Ipadu, Amazonian Coca

Although long neglected by anthropologists, Amazonian coca, *E. coca* var. *ipadu*, recently has been reexamined by botanists (Schultes 1957, 1981; Plowman 1979b, 1981; Rury 1981; Plowman and Rivier 1982; Plowman 1984a) and pharmacologists (Holmstedt et al. 1979). Amazonian coca is closely allied to *E. coca* var. *coca*, from which it has originated in relatively recent times (Plowman 1981). The Amazonian variety is cultivated on a small scale in small jungle plots by a number of tribes of the upper Amazon in parts of Colombia, Brazil and Peru. It is propagated by stem cuttings rather than by seeds, and entire plantations may represent a single clone; as such, it is well adapted to the pattern of shifting agriculture practiced by seminomadic Amazonian peoples. Amazonian coca does not survive as a feral or escaped plant in the lowland Amazon, and may be considered a true cultigen.

Bora tribesmen harvest Amazonian coca (*Erythroxylum coca* var. *ipadu*) at Brillo Nuevo, Río Yaguasyacu, Loreto, Peru. ©R. E. Shultes

Amazonian coca is little differentiated genetically from *E. coca* var. *coca*, and the two varieties appear to be fully interfertile. Amazonian coca contains the same leaf flavonoid profiles as Huánuco coca (Bohm et al. 1982). The principal chemical difference in Amazonian coca is a consistently lower cocaine content; this variety contains an average of only 0.25 percent cocaine, less than half the concentrations found in other cultivated cocas (Plowman and Rivier 1983). This low cocaine content has apparently led to the elaborate preparation of Amazonian coca leaves as a finely divided powder to which is added the ashes of *Cecropia* leaves as an alkaline source. The powder is mixed in the cheek with saliva and formed into a quid similar to the quid formed in chewing whole leaves. However, the Amazonian coca quid is completely swallowed as the leaf powder gradually dissolves (Schultes 1981; Plowman 1981).

Erythroxylum coca var. *ipadu* was unknown to Europeans until the middle of the eighteenth century. Details of its cultivation, use and geographic distribution were not recorded until the present century. Amazonian coca has no archeological record with which to date its origin in Amazonia. Based on linguistic, ethnographic, historical and botanical evidence, this variety appears to be a relatively recent development. It surely evolved from stocks of *E. coca* var. *coca* introduced from the Andean foothills through selection for traits conducive to its cultivation in Amazonia (Plowman 1981). It is now geographically isolated from other coca varieties and is not further implicated in the more complex evolutionary interactions that exist among the cultivated cocas of the Andean area.

Until the mid-1970s there was no commercial production of Amazonian coca. However, Colombian cocaine traffickers then discovered coca cultivation among certain Amazonian tribes. Although this variety is much lower in cocaine content than the traditional variety in the mountains of

With his cheek full of coca powder, a Bora tribesman toasts Amazonian coca leaves (*Erythroxylum coca* var. *ipadu*) at Brillo Nuevo, Rio Yaguasyacu, Loreto, Peru. ©L. Rivier

Colombia (*E. novogranatense* var. *novogranatense*), the traffickers found that it was easier to extract cocaine from the Amazonian variety. In addition, they found it was far easier to produce coca clandestinely in the remote *llanos* (plains) and Amazonian areas of eastern and southeastern Colombia. The effect of the Mafia invasion into traditional culture in these areas, and especially on the traditional and healthful use of coca, has been devastating.

Erythroxylum Novogranatense

Although *Erythroxylum novogranatense* is now recognized as a distinct species of coca, in the past it was often confused with, or considered a variety of, *E. coca* (Plowman 1982). Appreciable evidence now exists that suggests that this species arose as a domesticated plant through human selection from *E. coca* var. *coca* (Bohm et al. 1982). *Erythroxylum novogranatense* differs from *E. coca* in a number of morphological features, but, more importantly, it has evolved distinctive chemical and ecological traits and has become genetically isolated from parental *E. coca* var. *coca*.

Erythroxylum novogranatense consists of two well-defined varieties: *E. novogranatense* var. *novogranatense*, known as "Colombian coca," and *E. novogranatense* var. *truxillense*, known as "Trujillo coca." These two varieties are more strongly differentiated from each other than is *E. coca* var. *coca* from *E. coca* var. *ipadu*. This suggests greater varietal isolation and antiquity of differentiation within *E. novogranatense* than has occurred in *E. coca*.

Both varieties of *E. novogranatense* are known today only as cultivated plants. Both varieties are well adapted to arid conditions and usually are grown in areas where *E. coca* could not survive. In both alkaloid and flavonoid chemistry, *E. novogranatense* differs fundamentally from *E. coca*. Although cocaine concentrations compare favorably with *E. coca* var. *coca*, both varieties of *E. novogranatense* produce high levels of the related alkaloid cinnamoylcocaine, which is found in only small amounts in *E. coca* (Plowman and Rivier 1983). Methyl salicylate is also a conspicuous constituent of leaves of both varieties of *E. novogranatense*, but has not been reported in *E. coca* (Plowman 1982). The leaf flavonoids of *E. novogranatense* also differ from those of *E. coca* (Bohm et al. 1982). Finally, breeding experiments between *E. coca* var. *coca* and both varieties of *E. novogranatense* have demonstrated genetic differentiation among these taxa (Bohm et al. 1982).

Erythroxylum Novogranatense Var. Truxillense, Trujillo Coca

Trujillo coca is cultivated today in the river valleys of the north coast of Peru between about 200 and 1,800 m elevation, and in the adjacent arid, upper Marañon Valley. One disjunct cultivated population is known in the province of Carchi in northwestern Ecuador. It is grown today on a relatively small scale for coca chewing, and in northern Peru, as a flavoring for the soft drink Coca Cola as well.

Although Trujillo coca is a highly drought-resistant shrub, it still requires some irrigation throughout its range. In pre-Conquest times, plants were cultivated on elaborate irrigated terraces on the sides of the river valleys throughout coastal Peru. Today, plantations tend to be in flat areas in the valley bottoms where the plants are watered with more primitive irrigation canals. Shrubs of Trujillo coca are spaced well apart because of the scarcity of water, and individual shrubs are allowed to grow tall and bushy. These relatively large, sturdy shrubs are able to withstand the most severe droughts and will outlast most other crop plants in the area (Plowman 1979b, 1984a).

The leaves of Trujillo coca are smaller, lighter in color and more brittle than leaves of *E. coca*. Dried leaves of Trujillo coca contain an average of 0.72 percent cocaine (Plowman and Rivier 1982). Because it contains flavoring substances not found in *E. coca*, Trujillo coca was valued in the nineteenth century European and North American pharmaceutical industry for medicinal preparations. Because it is more difficult to extract and crystallize cocaine from Trujillo coca leaves, this variety is not commonly used for

Under the shade of the leguminous tree *Inga feuillei* in Simbal, La Libertad, Peru, a plantation of Trujillo coca (*Erythroxylum novogranatense* var. *truxillense*) grows. ©Timothy Plowman

commercial cocaine production (Plowman 1982; Plowman and Rivier 1983).

Trujillo coca is geographically and ecologically isolated from other coca varieties, and no hybrids between them are known. However, Trujillo coca has been crossed experimentally with *E. novogranatense* var. *novogranatense*; successful crosses were obtained in both directions. The resulting hybrids were vigorous and vegetatively normal, and exhibited morphological characters intermediate between the two parents. However, most of the hybrids that flowered showed only 50 percent pollen stainability and a much reduced seed set, suggesting at least partial reproductive isolation between these two varieties (Bohm et al. 1982). Trujillo coca was also crossed with *E. coca* var. *coca*. Although F_1 hybrids were obtained, they were morphologically and developmentally abnormal; many died as seedlings. They produced no flowers and clearly were ill-adapted for survival (Bohm et al. 1982).

While Trujillo coca is in several features intermediate between *E. coca* var. *coca* and *E. novogranatense* var. *novogranatense*, it is clearly most closely related to the latter, with which it also shares important chemical and ecological characteristics (Bohm et al. 1982). Trujillo coca is best classified in the species *E. novogranatense*, but must be recognized as a distinct variety within that species.

Based upon genetic and geographical relationships, it is highly suggestive that Trujillo coca evolved directly from *E. coca* var. *coca* through intensive selection for cultivation in drier habitats, and possibly for more delicate and flavorful leaves and a more robust, leafy habit. Trujillo coca subsequently gave rise to the Colombian variety of *E. novogranatense* in the northern Andes under similar conditions of geographic isolation and continuing human selection.

A flowering branch of Colombian coca (*Erythroxylum novogranatense* var. *truxillense*) cultivated at Collambay, La Libertad, Peru. Timothy Plowman

Erythroxylum Novogranatense Var. Novogranatense, Colombian Coca

The fourth variety of cultivated coca is *Erythroxylum novogranatense* var. *novogranatense*, known as "Colombian coca." This variety differs morphologically from other varieties by its bright yellow-green foliage and lack of persistent stipules. In dried leaf specimens, its identification may be more difficult and require anatomical study (Rury 1981). Colombian coca contains an average of 0.77 percent cocaine, along with relatively high concentrations of cinnamoylcocaine and methyl salicylate (Plowman and Rivier 1983).

Colombian coca is known only as a cultivated plant. Like Trujillo coca, this variety is well adapted to arid conditions and often is cultivated in the drier, inter-Andean valleys of Colombia and along the Caribbean coast. Today, however, it is grown mainly by a few isolated Indian tribes, primarily in the Sierra Nevada de Santa Marta, and in the departments of Santander, Cauca and Huila, up to about 1,800 m elevation. Colombian coca bushes are not grown in neat, terraced rows like Huánuco coca, but rather in small household plots on flat or gently sloping terrain. The bushes are widely spaced and are allowed to grow large compared to Huánuco coca.

Colombian coca is not extensively cultivated for cocaine production owing to the same difficulties in extracting cocaine that are found with Trujillo coca leaves. Colombian coca is used mainly for chewing and as a household medicine. It is also commonly planted as an ornamental and medicinal plant throughout Andean Colombia.

Unlike the other three coca varieties, Colombian coca is quite tolerant of diverse ecological conditions; for this reason, it was the variety introduced widely in horticulture in the last century and distributed to many tropical countries, both as an ornamental and source of cocaine (Plowman 1982). During the early part of the twentieth century it became an important cash crop in Java, where it had been introduced by Dutch colonial planters (Reens 1919a, 1919b).

In South America, Colombian coca is isolated geographically from other coca varieties, in contrast to the more complex distribution patterns seen in Trujillo and Huánuco cocas. This isolation has led to fundamental changes in the flavonoid chemistry and reproductive biology (Bohm et al. 1982). This variety will not cross with *E. coca* var. *coca*, although it will hybridize with Trujillo coca, producing vigorous hybrids albeit with reduced fertility. This suggests that Colombian coca is genetically closely related to Trujillo coca, even though some reproductive barriers between them have developed as a result of geographic isolation. Colombian coca is genetically much more distant from Huánuco coca.

In their breeding mechanisms, most *Erythroxylum* species are strongly self-incompatible, distylous species. Colombian coca is exceptional in being partially self-compatible, and isolated individuals may produce abundant viable seed. Self-compatability is considered a derived state in plants with a heterostylous breeding system. This fact favors the view that Colombian

An isolated shrub of Colombian coca (*Erythroxylum novogranatense* var. *novogranatense*) cultivated as a medicinal plant in a house garden at Trapiche, Cauca, Colombia.

©Timothy Plowman

A small planting of Colombian coca (*Erythroxylum novogranatense* var. *novogranatense*) at Ika village of Sogrome, Sierra Nevada de Santa Marta, Cesar, Colombia. ©Timothy Plowman

coca is the most specialized and most recently derived variety of the cultivated cocas (Bohm et al. 1982).

Archeological Evidence for Coca Chewing

The earliest archeological evidence suggesting coca is found in the Valdivia Culture on the Santa Elena Peninsula of southwestern Ecuador. Small ceramic lime containers thought to be used in coca chewing were found here that date to Valdivia Phase 4, about 2100 BC (uncorrected radiocarbon dating). A tradition of small, decorated lime pots extends through the Machalilla Culture to Chorrera times (1000-300 BC), when it reached its maximum development. A small, ceramic figurine of the Chagras style also was discovered at Valdivia that shows the prominent cheek bulge of a coca chewer. This piece is dated Late Valdivia (1600-1500 BC) and is the earliest known example of a long Ecuadorian tradition of figurines depicting *coqueros* (coca chewers) (Lathrap et al. 1976). Skulls containing heavy accumulations of dental calculus, interpreted as an indication of heavy coca chewing with lime, have been found in a late Chorrera cemetery on the Santa Elena Peninsula (Klepinger et al. 1977). Based on archeological evidence, it appears that coca chewing, and perhaps coca cultivation, were fully established in the Valdivia area by 3000 BC.

Early evidence for coca chewing has been found also on the Peruvian coast in the Late Preceramic Period 6 (2500-1800 BC) in the form of coca-

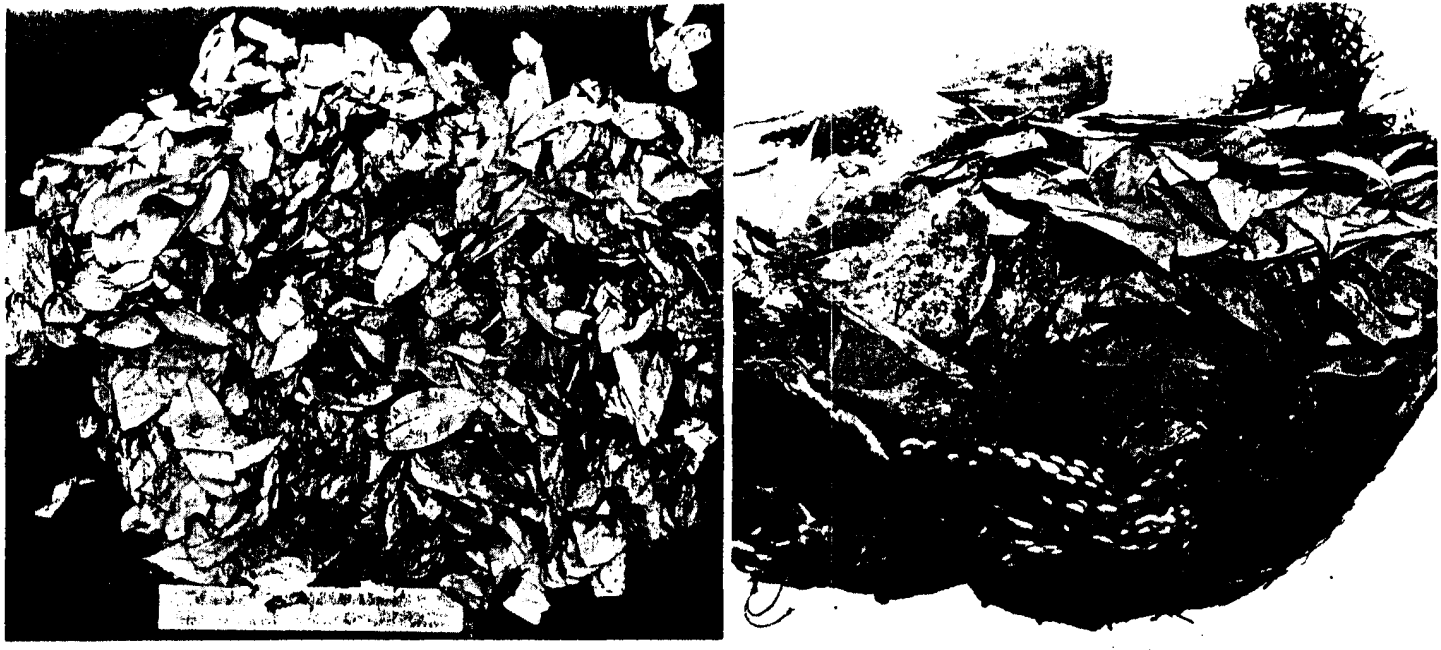
chewing paraphernalia and possibly coca leaves themselves, although the botanical material was not identified taxonomically. Engel (1957) reported a bottle gourd and three *Mytilus* shells, all containing powdered lime thought to be used with coca, from a burial at Culebras, a site dated at 2000 BC by Bray and Dollery (1983). Engel (1963) found "leaves looking like coca" along with large deposits of burnt lime at Asia in the Omas Valley. Asia is radiocarbon dated at 1314 BC ± 100, but probably dates to about 1800 BC (M. Mosely, personal communication). Patterson (1971) excavated preserved coca leaves near Ancon in the Gaviota phase dated between 1900 and 1750 BC. Coca was one of the items (along with maize and marine shells) stockpiled in a group of storage structures at Huancayo Alto in the Chillón Valley, dating between 800 and 200 BC (Dillehay 1979). Unfortunately, none of these early records of preserved coca leaves has been botanically identified because none of the original specimens can be located.

Later sites, principally burials, on the Peruvian coast have yielded verifiable archeological coca leaves. Specimens from sites ranging from Lima south to Africa in northernmost Chile were studied morphologically and anatomically and found to correspond closely with modern Trujillo coca, *E. novogranatense* var. *truxillense*; generally the archeological leaves were smaller in size (Rury and Plowman 1984). Earlier authors, unaware of the existence of the Trujillo coca, assumed that archeological coca from coastal Peru was Huánuco coca that originated from the eastern Andes, and they suggested that this showed extensive, early trans-Andean trade from the montaña to the coast (Sauer 1950; Lanning 1967; Lathrap et al. 1976; Klepinger et al. 1977; Cohen 1978; Dobkin de Rios and Cardenas 1980). Although trade in coca from the montaña to the coast may have occurred on a small scale, there is little evidence for it from archeological remains. Because of wet conditions in the montaña and highlands, no early specimens of archeological Huánuco coca leaves have been found (Plowman 1984b).

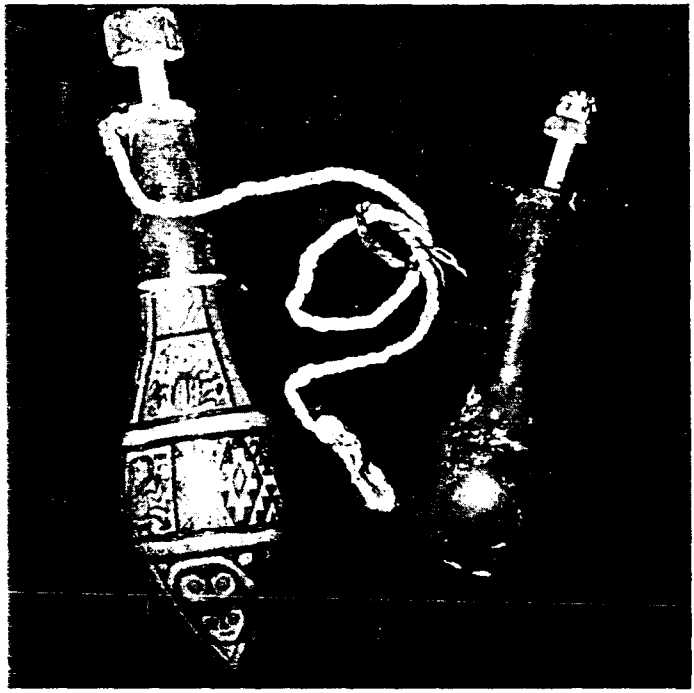
Further evidence for coca chewing, including lime pots, lime dippers and ceramic, coca-chewing human figurines, as well as occasional preserved leaves, has been found throughout the Peruvian coast from the early ceramic period to Inca times. Both Nazca and Moche ceramics depict numerous examples of coca chewers with cheek bulges, often carrying lime gourds and dippers (Yacovleff and Herrera 1934; Jones 1974; Donnan 1978; Jeri 1980).

Following the early appearance of coca chewing during the Formative Period in Ecuador, representations of coca chewing in the form of lime pots and coquero figurines are found in all later phases up until Inca times, especially in the provinces of Manabí, Esmeraldas and Carchi (cf. Meggers 1966; Drolet 1974; Naranjo 1974; Jones 1974; Bray and Dollery 1983).

In Colombia, there is abundant archeological evidence for widespread coca chewing in the form of coca-related artifacts. During the first millenium AD, the Quimbaya Culture of the middle Cauca Valley produced numerous, beautifully crafted, gold lime pots and lime dippers. In addition,



Left: Dried leaves of Colombian coca (*Erythroxylum novogranatense* var. *novogranatense*) ready for chewing, as sold in the Sunday market at Silvia, Cauca, Colombia. ©Timothy Plowman. *Right:* Cotton bag containing Trujillo coca leaves (*Erythroxylum novogranatense* var. *truxillense*) from an Inca cemetery, Atarco II site, Nazca, Taruga Valley, Ica., Peru. Wattis Collection, Accession no. 16-13426, Lowie Museum of Anthropology, University of California, Berkeley. Photograph courtesy of the Lowie Museum of Anthropology.

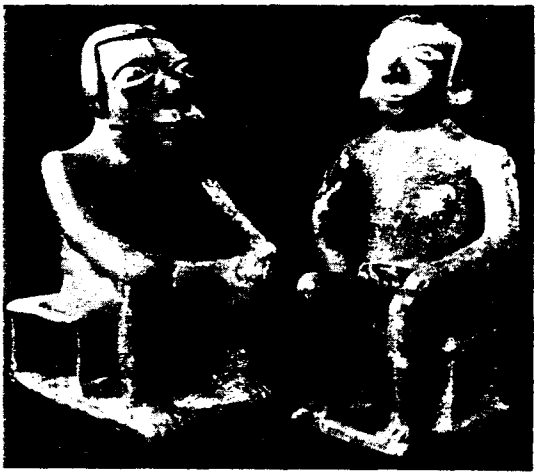


Archaeological lime gourds (*Lagenaria siceraria*) from coastal Peru. The larger decorated specimen is from Huaura Valley, ca. 1000-1275 AD; the smaller undecorated specimen is from Cajamarquilla, Rimac Valley, date uncertain. Peabody Museum of Archaeology and Ethnology, Harvard University. ©Timothy Plowman

gold figurines carrying lime pots have been found in this culture area (cf. Jones 1974; Antonil 1978; Bray 1978; Hemming 1978). Ceramic lime pots representing coca chewers are also known from Colombia.

In the San Agustín culture of southern Colombia, several monolithic statues have been found that strongly suggest coca chewing by the presence of extended cheek bulges and small bags (for coca leaves) slung across their chests (Perez de Barradas 1940; Uscategui 1954; Reichel-Dolmatoff 1972; Antonil 1978). The San Agustín statues are dated approximately to the first millenium AD. The town of San Agustín long has been, and continues to be, a major center of coca cultivation and distribution in the upper Magdalena Valley.

Archeological evidence that coca chewing reached Central America exists but is of a considerably later date than related findings in South America. Lothrop (1937) reported a small, carved bone head with a prominent cheek bulge from Sitio Conte in the Cocle culture of Central Panama, dated between 500 and 700 AD. This figurine closely resembles figurines from Manabí Province in coastal Ecuador as well as the early Valdivia figurine discussed above. Stone (1977) mentioned small figures of gold and stone from the Diquis region of Costa Rica that show the characteristic cheek bulges of coca chewers.



Ceramic figures of coca chewers of the Capuli style from Nariño, Colombia, 800-1250 AD. Right figure from Museo de Oro, Accession no. CN 3115; left figure from Museo Arqueológico del Banco Popular, Bogotá, Accession no. N-8511. Robert Feldman

Of all the areas from which we have evidence for archeological coca chewing, only in coastal Peru has it been possible to identify the variety of coca used because of its remarkable preservation in the desert environment. Trujillo coca appears here around 1800 BC, although it probably arose elsewhere (see below). Although we have no direct evidence from archeological leaves, it may be assumed that *E. coca* var. *coca* was being cultivated and used for chewing much earlier in the east Andean montaña of Peru and Bolivia. Both Trujillo and Huánuco coca probably were used in parts of Ecuador, where appropriate dry and wet habitats for these varieties exist. Colombian coca was certainly the variety employed in the mountains of Colombia, along the Caribbean coast and probably in Central Panama (Plowman 1984a, 1984b).

The Discovery, Evolution and Early Diffusion of Coca

The following scenario for man's first discovery and cultivation of coca in the montaña has been outlined earlier (Antonil 1978; Plowman 1979a, 1984a, 1984b; Bohm et al. 1982). The palatable, relatively tender, young leaves of *E. coca* var. *coca* must have been sampled first as a famine food by groups of nomadic hunter-gatherers who early inhabited the eastern Andes. At this time, coca existed as small, scattered wild populations in the montaña, similar to the distribution patterns of many wild species today. The stimulant and medicinal properties of the leaves were discovered, probably more than once, during this early period of experimentation. Once the stimulating effects of the leaves were known, they were routinely gathered from the forest for daily use. Refinements in the use of coca, including sun-drying the leaves, holding them in the mouth as a quid, and the addition of an alkaline substance, gradually developed and became customary. Numerous alkaline sources have been employed in chewing coca as with

other drugs such as tobacco. In the montaña, the simplest and most readily available alkaline source is the ashes prepared from a wide variety of plants (Plowman 1980; Rivier 1981).

As supplies in the wild became insufficient to meet the needs of a growing, coca-chewing population, coca shrubs were transplanted from the wild, nearer to habitations so that a constant supply of fresh leaves would be available. In this context, coca must have been one of the earliest plants cultivated in the montaña and must be implicated in the earliest development of agriculture in this area. The first use and cultivation of coca certainly antedates the first appearance of any archeological evidence (such as ceramic representations of coca chewers or coca-chewing paraphernalia) by several thousand years.

Based on botanical and chemical evidence cited earlier, Trujillo coca is thought to be an intermediate between Huánuco coca and Colombian coca, forming a linear evolutionary sequence (Bohm et al. 1982). Although the area of origin of Trujillo coca remains a mystery, it is possible that this variety evolved from populations of Huánuco coca in adapting to drier habitats as man extended the range of coca into new areas. The most likely areas for this to occur are the more arid Andean valleys that lie adjacent to the wetter montaña habitats of Huánuco coca. Interspersed throughout the central montaña are locally drier valleys, such as the Tarapoto basin in San Martín and La Convención in Cuzco, where Huánuco coca can still be cultivated. However, this variety is not found in the adjacent arid, thornscrub areas of the upper Marañon and its tributaries in northern Peru. This is precisely the kind of habitat where plantations of Huánuco coca are replaced by the Trujillo variety.

At some unknown, early date, populations of *E. coca* var. *coca* were adapted to successively drier valleys through a long period of gradual selection for successful cultivation in these areas. Many intermediate forms must have developed during this time in isolated valleys, and some hybridization must have continued to occur among them. Eventually genetic barriers to such hybridization developed, resulting in the genetically stable species *E. novogranatense* (as var. *truxillense*). Although certain crucial areas of northern Peru remain to be explored for possible intermediates, no natural hybrids between Huánuco and Trujillo coca have been observed.

Once Trujillo coca became established as a species, it was taken to new arid areas that were previously inhospitable for coca cultivation. It is possible that this variety of coca was cultivated at an early Valdivia site on the arid Santa Elena Peninsula in Ecuador 5,000 years ago and later diffused southward along the desert coast of Peru, where it appears in archeological sites around 2000 BC. This early Ecuadorean distribution for Trujillo coca is supported by the discovery in 1978 of isolated, remnant patches of this variety being cultivated in Carchi on the Pacific slope. These populations lie far from the only other existing populations of Trujillo coca in northern Peru and may be remnants of plants once widely grown along the coast of Ecuador (Plowman 1979a, 1984b; Bohm et al. 1982). Unfortunately, coca

was almost completely eradicated in Ecuador owing to the incessant persecution of coca chewing by ecclesiastic and government officials that began in the sixteenth century (Leon 1952; Gagliano 1960, 1976; Naranjo 1974). This persecution succeeded in eliminating most of the germ plasm that could have answered key questions about the early evolution of the plant.

The hypothesis that Trujillo coca appeared very early in Ecuador is complicated by the existence of Huánuco coca in moist, forest areas on both sides of the Ecuadorean Andes. Because we lack archeological coca specimens from Ecuador, it is impossible to know with certainty which variety was used at Valdivia or other archeological sites in Ecuador. But it is certain that coca was widely cultivated and employed prior to the European invasion, possibly as a result of the earlier Inca expansion into present-day Ecuador (cf. Meggers 1966; Patiño 1967; Drolet 1974; Naranjo 1974; Lathrap et al. 1976). It is entirely possible that both Trujillo and Huánuco coca varieties were cultivated in their respective ecological zones in pre-Columbian Ecuador.

Similar to the mechanisms by which Trujillo coca originated through selection and isolation in drier areas of northern Peru or southern Ecuador, it is likely that Colombian coca arose in the isolated mountain valleys of southern Colombia, from populations of Trujillo coca in Ecuador. Through continuing selection, Colombian coca differentiated as a distinct variety, but did not diverge sufficiently to become a separate species. It then diffused throughout the mountains of Colombia, to the coast of Venezuela and northward into Central America (Bohm et al. 1982; Plowman 1984b).

It is significant that the four cultivated cocas are completely allopatric in their geographic ranges, and no hybrids have ever been found in areas between these ranges. They remain morphologically, chemically, genetically and ecologically distinct. This is the result of several thousand years of cultivation, selection and diffusion throughout the tropical Andes by peoples who very early learned to appreciate the unique qualities of the coca leaf.

Future studies on the origin and evolution of coca will follow various directions, including biochemical comparisons of extant varieties and further investigation of documented archeological remains. Most urgent, however, is the need for extensive field work on remaining coca varieties in South America in order to document the many local forms that exist. An intensive effort in Ecuador is required to search for any relictual populations of coca, especially on the coast. The discovery of any indigenous coca plants in Ecuador is likely to provide key botanical, chemical and possibly ethnographic data for resolving several unanswered questions on the evolution of the plant.

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