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Climate, human, and natural systems of the PEP II transect

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Abstract

The purpose of this introduction is to provide a background to the natural and human environmental systems on the Austral-Asian (or PEP II) transect. Aspects of these systems are discussed in greater detail in the papers that follow in this volume. Focusing on the distinctive characteristics of the PEP II transect, this paper begins with an overview of the main physical features, reviews the nature of the present climate systems and concludes with an outline of the patterns of human settlement across the region and the diversity of environmental interactions between these and human societies.

1. The main physical features of PEP II

The PEP II transect includes features that have predisposed parts of the Austral-Asian region to respond in unique ways to past global environmental changes. Furthermore, it can be argued that some of the features are significant drivers for environmental change across the whole planet, although establishing this linkage requires evidence from key areas with a time resolution that permits better comparisons than is currently possible. What is immediately striking is the broad range of environments across the region.

Ice cover has probably been less significant in Austral-Asia than on the other PEP transects of the Americas (PEP I) or Europe-Africa (PEP II). For Austral-Asia, this is due to the location of uplands in relation to the large synoptic scale climate features. During the last glacial cycle the area covered by ice was not greatly larger than today (CLIMAP, 1981; Mix et al., 2001). There was no large ice sheet as in North America or Europe, and the largest area of uplands, the Tien Shan and Tibetan Plateau, is located in the interior of Asia and well away from significant moisture sources to form ice caps. Indeed a major feature of glacial climates in Asia and Australia has been the greater dust load in the atmosphere and a greater extent of desert and semi-arid lands compared to today (Sun et al., 1998; Nanson et al., 1992). In the tropics a small ice cap formed on the mountains on the island of New Guinea (Allison and Peterson, 1976), and ice was more extensive over South Island, New Zealand, plus there were small areas of ice accumulation on the highest mountains of Siberia, China, Mongolia, Korea, Japan, Taiwan, Indonesia and Australia. These had local significance in terms of ecological change, and on humans where they were present, but probably little direct role as global forcing factors. The tropical glaciers are in retreat at present, possibly as a result of global warming, but the New Zealand glaciers show periods of expansion in relation to rainfall increases (Follard and Karl, 2001).

While direct ice cover was not globally significant, China, Siberia and northern Sakhalin Island contain the world's largest areas of permafrost (Zhang et al., 1999). These were probably more extensive during the last glacial maximum (LGM) (e.g. Shi, 2002) and then and today they influence the distribution of taiga, tundra and bog. Little is known of the environmental history of these regions but many of the large valleys today have permafrost exposures and retreat is leading to erosion and valley widening. Permafrost retreat is accompanied by release of entrapped methane, and understanding the dynamics of these systems is important to studies of the global greenhouse gas budget.

The highest and most significant plateau and highlands on Earth occupy an area of central Asia between the Indian subcontinent, China, Pakistan, Kyrgyzstan

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and Kazakhstan (Fig. 1). This area has a relatively recent geological history, with major periods of uplift taking place in the Miocene, Pliocene and Quaternary periods. It has had a profound influence on global climates and natural hazards. The Tibetan Plateau has been said to act like a 'Third Pole', but because of its mid-latitude position it splits the westerlies in winter and warming from its surface drives the summer monsoon systems from the south and east. Its mid-continental location means it has had only relatively small areas of ice cover in the Quaternary and it creates a rain-shadow of desert regions from Xinjiang and across Qinghai, Gansu and Mongolia. Ice and snow cover on the central Asian plateaus would have had high dust contents and therefore relatively low albedos compared to other areas of ice. This would diminish the circulation of the Asian Monsoon, which is the most important heat conveyor from the tropics to middle latitudes in the Northern Hemisphere, and alter the pattern of migration of the westerlies.

A further important role of environmental change on the Tibetan Plateau is its affect on dust supply. The production of fine sediments by glaciation and periglaciation, and stronger wind from an enhanced winter monsoon and the westerlies leads to a much greater dust transport (Ono and Naruse, 1997). Downwind of the region the deserts contribute high dust loads into the atmosphere and these deposit huge quantities of aerosol to the Loess Plateau area, up to hundreds of metres in thickness (Liu, 1985), and across eastern Asia, Japan, the north Pacific and occasionally into North America (Zhang et al., 2002). Modeling has also suggested that the uplift of Tibet has altered the circulation patterns of the Northern Hemisphere and through monsoon circulation (Ruddiman, 1997) there has probably also been a linkage into the Southern Hemisphere. Thus it can be argued that snow and ice cover change on the Tibetan Plateau can play a role in global forcing. The discovery of Dansgaard–Oeschger cycles in loess (An and Porter, 1997), and in ocean cores in the Sea of Japan (Tada et al., 1999) and South China Sea (Wang, 1999) suggest there are teleconnections with the PEP I and PEP III transects.

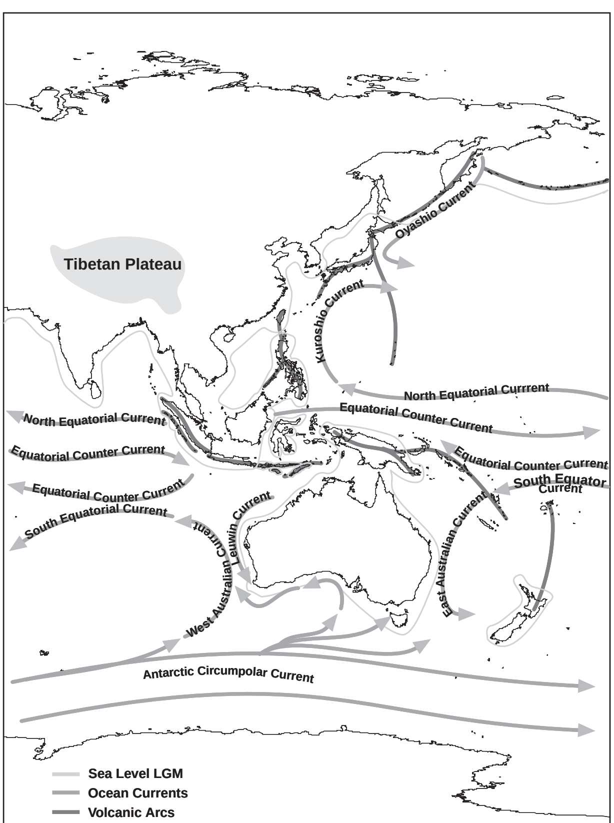

Fig. 1. Map of main physical features, including Tibetan Plateau, LGM sealevel, ocean currents, volcanic regions.

Australia, by contrast, is an old continent with a highly weathered surface, low relief and with a mid-latitude location. The Australian Subtropical High creates an arid core and as a result is probably the major source of dust in the Southern Hemisphere. Humid conditions occur in the north where there is a summer monsoon, the far south where there is influence from the westerlies and along the eastern seaboard where moist air comes on shore from the NE Trade Winds and from easterlies off the Tasman Sea. The timing of these is influenced by the seasonal latitudinal migration of the Australian Subtropical High. It also suggests that an enhanced Northern Hemisphere winter monsoon will be accompanied by a stronger Australian summer monsoon.

The PEP II region therefore contains significant areas of desert, and provides the major dust loadings to the atmosphere of both hemispheres. We know from high-resolution records from the Loess Plateau in China that the dust load in the Northern Hemisphere has varied on Milankovitch time scales and also contains low frequency but high magnitude events on other time scales (An et al., 2001). We do not have the same detail for the Southern Hemisphere, but modulation of insolation by dust is likely to have been an important climate control, and from Holocene time there were both natural and anthropogenic components to the size of the dust loading.

An outstanding feature of the region is the development of a series of marginal seas, from the Bering Sea in north to the Tasman Sea in south, with the world's largest lower-latitude continental shelves (Fig. 1). Solely three of those, the East China Sea shelf, the Sunda shelf and the Sahul shelf, sum to nearly 4 million km^2, comparable to the entire Indian Sub-continent in area. The most striking geographic alteration of the PEP II region in the LGM was the emergence of vast shelf areas. Together with the decrease in sea surface temperatures (SSTs), the glacial exposure of the shelves significantly reduced the heat and humidity transport from the ocean to the land, causing intensified aridity in the Asian hinterland (Wang, 1999). The emerged land-masses would have also provided broad corridors for dispersal and migration of plant and animal species (including humans). The coastline migration during the deglacial transgression would have reached enormous rates on the vast shelves, e.g. with a rate of 0.4 m/day on the East China Sea shelf, giving the 1200 km distance from the shelf break to the Bohai Gulf coast east of Beijing.

The four marginal seas between East Asian and Pacific (Okhotsk Sea, Sea of Japan, East and South China Seas) make up a hydrographic system and modify the material and energy exchanges between the largest continent and the largest ocean. For example, the marginal seas capture a major part of terrigenous flux from the land, thus explaining the absence of large deep-sea fans in the NW Pacific. Since the connections between the marginal seas with the open Pacific are usually through narrow and/or shallow seaways, the system is highly sensitive to sealevel changes. At present, the western boundary is the warm Kuroshio Current (Fig. 1) which enters the East China Sea and flows northeastward, while its north branch, the Tsushima Warm Current, crosses the Korean Strait, enters the Sea of Japan and then runs through the Soy Strait into the Sea of Okhotsk. On the other hand, the Kuroshio water also propagates into the northern South China Sea and hence flows through all the four marginal seas, mixed with fresh water from the continent. During the LGM, there is evidence to show that the influence of the Kuroshio warm water was minimal, suggesting that the Kuroshio was running northward largely bypassing the marginal seas (Li et al., 1997; Tada et al., 1999).

The changes in the marginal seas system have had significant climatic and oceanographic impact in the PEP II region. The absence or decrease of the Kuroshio water explains, for example, the abnormally low SST in the glacial East and South China Seas and the enhanced contrast between the northern and southern parts of the South China Sea (Wang and Wang, 1990). The cutoff of the oceanic water supply during the glacial was responsible for the dilution of surface water and hence the stratification of water column in the Sea of Japan (Oba et al., 1991; Tada et al., 1999), and also for aridity in Japan due to the decrease of vapor supply from the then ice-covered surface of the Sea.

The world's greatest oceanic 'Warm Pool' is located around Indonesia and New Guinea. This is the major source of atmospheric moisture since sea-surface temperatures generally exceed 29°C. The switching on and off of this moisture source through sealevel variation would have had both regional and global implications, for example in controlling the vigor of ENSO. Indeed, recent research has suggested a role for the Pacific Warm Pool in global climatic variations associated with the Little Ice Age (Hendy et al., 2002). An intense Low forms over the 'Warm Pool' and is responsible for transferring a significant amount of heat from the ocean to the atmosphere, and this rising branch of the Walker Circulation brings high rainfall throughout the Indonesian region. Under a lower sealevel, as at LGM, the role of the 'Warm Pool' would have been greatly changed, perhaps to the point where ENSO was not operative and the northern Australian monsoon was severely weakened.

A further distinctive feature of the PEP II transect is the level and extent of tectonic activity and the number and diversity of active volcanoes, due in part to the density and complexity of subduction zones between adjacent continental and oceanic plates (Fig. 1). Associated with this past and active history of tectonic and volcanic activity are a host of natural hazards, including earthquakes, tsunami, landslides, lahars, and pyroclastic flows. The abundance of volcanoes and the depth of the historical record mean that in some places there are particularly good records of past volcanic events, for example in Japan and New Zealand (e.g. Machida and Arai, 1992) and New Zealand (Page and Trustrum, 1997; Lowe et al., 1998). There are a number of well-known tephras that are valuable time markers in both terrestrial and marine sequences. The potential to develop more of these from Indonesia and across the Philippines, and in the north in Kamchatka is high (e.g. Yamagata et al., 1999; Igarashi et al., 1999).

2. Modern climates and their variability

The climate of the Asian mainland is dominated by the position of the Siberian High, the jet stream (which is split and deflected by the Tibetan Plateau) and the summer and winter monsoons. East of the Asian mainland the warm currents in the ocean around Japan mean that the westerlies and easterlies from the North Pacific High bring abundant precipitation to Japan and the adjacent coasts of Korea, Siberia, South China and Taiwan (Figs. 1 and 2). This is related to the East Asia summer monsoon, which is related to activity of a Pacific Polar Front and the Pacific Subtropical High. Cyclones originating in tropical and subtropical regions in the south may affect the climate of southern China and adjacent islands from spring to autumn, however in summer they may extend as far north as the southern coasts of Japan and Korea, bringing intense storms. The interior of Asia is dry (< 50 mm/yr) because few rain-bearing systems penetrate from any direction (Fig. 2). The east and south of Asia has abundant summer rain and this is separated from the arid interior by a transition zone where rainfall may penetrate from the

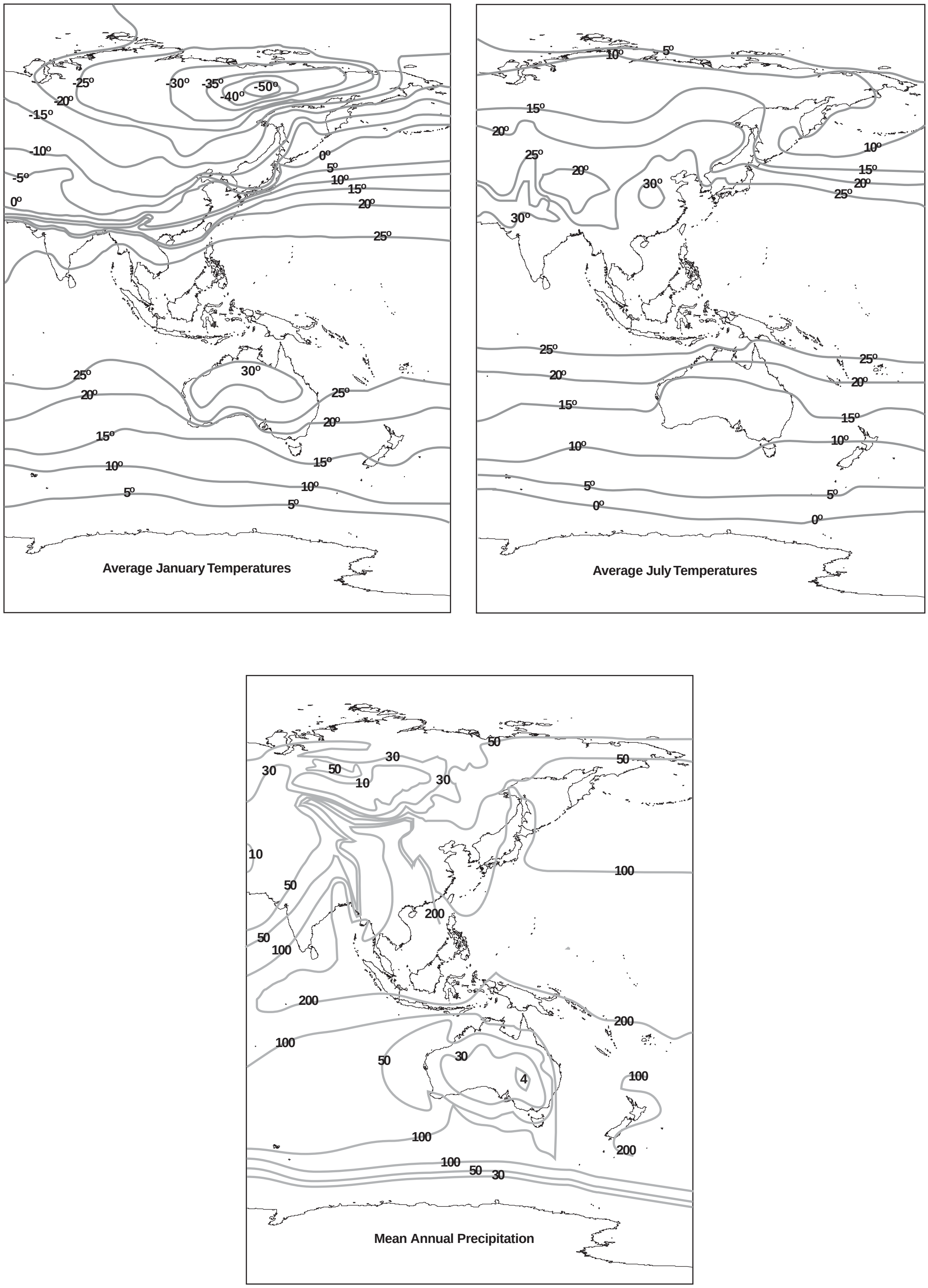

Fig. 2. Climate features for January and June for both hemispheres in the PEP II region.

monsoon systems from time to time. The very dry air masses that leave Asia can pick up abundant moisture across the Sea of Japan that eventually falls as massive snow accumulations on the western mountains of Honshu and Hokkaido.

Temperature gradients generally reflect latitudinal zones except where they are modified by mountains. The altitudinal range is such that true alpine regions occur widely in the Himalayas, eastern Tibetan Plateau and Taiwan in the warm temperate zone. The timberline descends to about 5000 m in the Himalayan, 4000 m in Taiwan, 2500 m in central Honshu, 1500 m in Hokkaido and 100 m in Kamchatka. In the southern Tien Shan, Dunlin and Kunlun the air is so dry that grasslands from the desert floor eventually give way to permanent snow with no intervening forest zone. However, mountains facing the Summer Monsoon have a wide range of forests because of the humid and temperate climate. Mountains exceeding the snowline are limited to Karakorum, Himalaya, in the Inkling and Altai Shan, isolated peaks from Shaanxi and Shanxi to Jilin in China, and in the Korean Peninsula and in Japan because of the relatively high temperatures in summer. The Asian region is therefore marked by having enormous precipitation gradients from >2500 mm/yr to areas with less than 50 mm/yr mean annual rainfall (Fig. 2).

Tropical regions along the PEPII transect have climates strongly influenced by their proximity to the Western Pacific 'Warm Pool'. This generally brings abundant all-year rainfall, but in places high mountains can create rain-shadow effects and relatively dry regions may be found as for example in Sulawesi and New Guinea. The natural variability of the monsoons and ENSO modulate rainfall. The variability of ENSO appears to have become greater in the last few decades and drought and associated bushfires and burning have resulted, even in regions with high mean annual rainfall. Islands in the western Pacific tend to have relatively high rainfall although this is also modulated by ENSO variability. Across the tropical region temperatures are hot all year round except on the higher mountains of Indonesia and New Guinea.

Australia's mid-latitude position ensures a Subtropical High is located over its landmass. Temperatures are mild to hot (Fig. 2). The only significant high country occurs in the southeast and Tasmania, where temperatures are moderated and some local rain-shadow areas occur. Much of the continent is sub-humid to arid, with a weak summer monsoon bringing most of the precipitation that is received in the north. The Subtropical High migrates seasonally from central Australia in winter to south across the Great Australian Bight in summer. This means that the southerly fronts which sweep off Antarctica and across the Southern Ocean bring winter rainfall to the southwestern and southeastern areas of the continent. Tasmania and the far southern coasts sit within the westerlies and may receive rainfall throughout the year. The eastern part of Australia, in particular, comes under the influence of ENSO and years of drought alternate with above average rainfall. In general precipitation patterns are marked by their great variability, and mean annual rainfall is a poor descriptor of them, especially in inland Australia which is poorly served by rain-bearing systems from any direction. In reality many areas of the interior receive much of their rainfall from the occasional incursion of tropical cyclones which originate along the Indian Ocean coast, or less frequently in the Timor or Coral Sea.

New Zealand has a unique set of climate circumstances. It has high relief orientated approximately SW–NE and most of it lies across and within the Southern Hemisphere westerly wind-stream. The mountains are high enough for alpine conditions, especially in South Island, and in the lowland temperatures are relatively mild all year, befitting its maritime setting. Rainfall is very high on the west coast of South Island while in the rain-shadow areas rainfall is less than one-third on the lee side. The far north of New Zealand has a very mild climate which is almost subtropical in character.

3. Vegetation along PEP II transect

The natural vegetation of PEP II reflects the complex history and variety of environments across the region (Fig. 3). The north and east Asian regions have vegetation with much in common with boreal and temperate Europe and North America. The south and tropical regions have a flora, which is dominated by Indo-Malayan elements. These are generally considered to have evolved in the region from a mix of ancient Gondwanan and Laurasian elements. High endemism characterizes the Australian flora because of its long period of isolation, and it is regarded as a biogeographic realm in its own right. As the Australian and Asian plates came into greater proximity during the Cenozoic the opportunity for exchange in floras and faunas was increased. Some exchange in Indo-Malayan and Australian elements has occurred but there remains a biogeographic divide (Wallace's Line) that highlights the distinctiveness of the regions. New Zealand has a highly endemic flora which is strongly Gondwanic in origin.

In summary, the regional vegetation patterns in some cases reflect a long history of isolation and in other cases exchange. There is extensive tundra, taiga, boreal and temperate forests in the north, rainforests and mangroves systems in the tropics and subtropics in both hemispheres and arid shrublands in Central Asia, northwest India and Australia. Tropical grasslands are virtually absent outside of Australia and the alpine vegetation is distinctively different in the greatly separated regions of New Zealand, southeast Australia, New Guinea, and the highlands of Japan and continental Asia (Fig. 3).

There is a strong correlation between vegetation distribution at the biome level and climate parameters (Prentice et al., 1992). Koeppen (1936), Holdridge (1947) and Kira (1948) provide the basic tools for comparing vegetation to climate regimes. In many areas

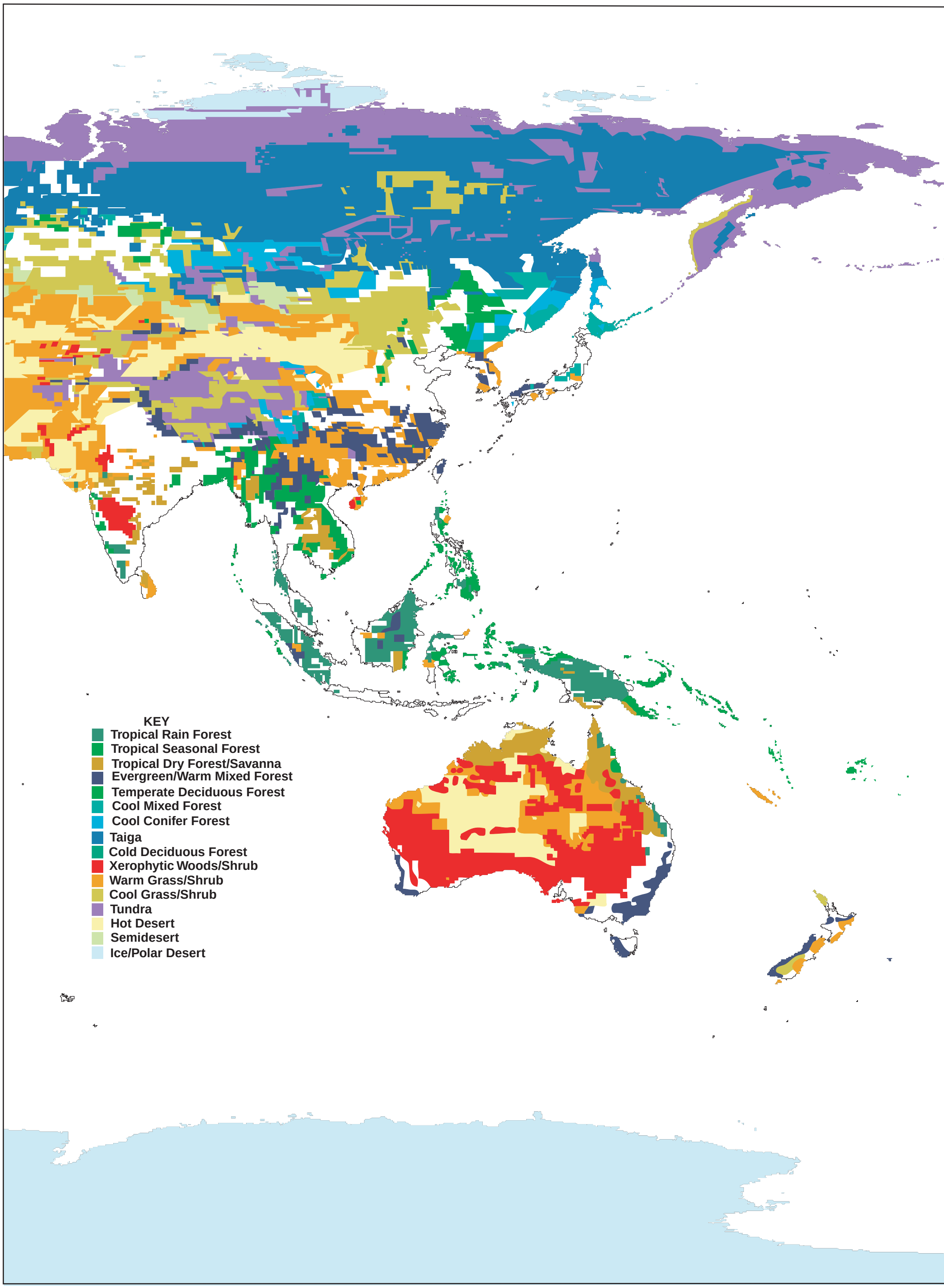

Fig. 3. Vegetation map of the PEP II region, based on Olson et al. (1983) and Prentice et al. (1992).

of the transect vegetation has been severely modified by human activity, and the degree of modification usually reflects some combination of the length of settlement, population density and intensity of land use. The change from natural vegetation is so great that in some cases global vegetation maps do not record what the natural vegetation cover was.

Tundra occurs across the northern region of Siberia and Kamchatka, and most of the growth forms are ground-hugging or with other warmth-preserving mechanisms. Some deciduous shrubs may be present. The climate is typified by a growing season of 6–10 weeks and long, cold dark winters with 6–10 months of mean temperatures below 0°C and low precipitation. There is often no real soil development and permafrost is common and is often the main factor in preventing tree growth. Alpine tundra extends widely across the Himalaya-Karakorum and Tibetan plateaus

Taiga or boreal forest exists as a continuous belt across Eurasia from about 50–35°N latitude. The dominant plants are needle leaf trees of species of *Picea*, *Abies*, *Pinus* and *Larix*. Some broadleaf species of *Betula*, *Populus* and *Alnus* can occur in early successional stages. The climate is typified by long harsh winters of about 6 months of below freezing temperatures and 1.5–3 months of frost-free days. Mean annual precipitation is typically 400–500 mm/yr but the low evaporation means the climate is relatively humid. The extreme continentality and permafrost in eastern Siberia provides a vast area where *Larix dahurica* dominates.

A temperate broadleaf deciduous forest occurs in northeastern China, upland and northern areas of Japan and on the Korean Peninsula. Main taxa present include species of *Quercus*, *Fagus*, *Castanea*, *Alnus*, *Ulmus* and *Juglans*, and these dominate over a rich understorey of shrubs and herbs. The forests may reach 30 m in height especially where the growing season is above 6 months. Precipitation of 500–1500 mm/yr is normally distributed throughout the year and usually any non-growing season is due to temperature-induced drought, even in cold winters. The forest is still partly intact in the mountain areas of Korea, Taiwan and Japan. By comparison, forest has been heavily modified in China since the mid-Holocene.

Temperate forests in the Southern Hemisphere are quite different from those of eastern Asia. They occur as species of *Araucaria*, *Agathis*, *Nothofagus* and Podocarpaceae, and are distributed in upland New Guinea, New Caledonia, New Zealand and cool-wet areas of eastern Australia. They grade into tall wet forests dominated by several *Eucalyptus* species in the east and south west of Australia. The climate envelopes of these southern forests are similar to those of their northern counterparts, although fire is often a significant feature in the Australian region.

Tropical rainforests occur throughout lowland southeast Asia, southern India, and across non-rain-shadow areas of Indonesia, southern Philippines, New Guinea, tropical Pacific Islands and in well-watered areas of northern and northeastern Australia (Fig. 3). Mean monthly temperatures are usually above 18°C and precipitation is abundant and often above 2500 mm/yr. Any dry season is short and more than compensated by abundant rainfall at other periods of the year. The vegetation is characterized by emergent umbrella-shaped canopy trees above a closed forest of smaller trees. Light becomes a limiting factor for understorey and low shrubs and herbs are sparse if present. Subclimax communities occur on floodplains and where cyclones have caused damage. The species composition is complex; often 10 times as many as in temperate forests; and species and even genera and families may be different from place to place. In alpine tropical regions distinct vegetation communities exist and these are rarely similar to latitudinal vegetation types found in temperate zones.

Tropical savannas or grasslands are associated with wet and dry seasonal climates. Savannas develop where the dry season is three months or more, and their composition is often controlled by a combination of soil conditions, fire frequency and disturbance. Temperatures are similar as for tropical rainforests and the dry season is defined as at least 3 months with precipitation below 100 mm/month. In the PEP II region they are predominant in India, southeast Asia, northern Philippines and central Australia. In southeast Asia these are often considered to be due to human impact. Main taxa are related to rainforest genera and families of Indo-Malayan origin while in Australia various species of *Eucalyptus* and *Acacia* dominate. At the drier end of these sequences tall grasslands (1–2 m high) often dominate, and some of these occupy the same climatic zones as does thorn scrub in Africa.

Desert areas occupy a large area of the PEP II region and they are usually found where a zone of high pressure is centred over a continental landmass (Fig. 3). The rainfall is generally below 250 mm/yr and potential evaporation greatly exceeds precipitation for many months or even a full year. Temperatures are continental in nature, with high daytime temperatures falling by 10–15°C at night. Winters are cool to cold and snow and frost may occur. Desert vegetation is found in northeastern India, across central Asia to Mongolia, and in central Australia. The vegetation is mainly evergreen but may include deciduous species. The shrubs that dominate are able to withstand extreme drought and they form a sparse and discontinuous canopy. Deserts also have extensive growth of annuals after rain. Succulents are uncommon compared to desert regions in Africa or the Americas, but Compositae and Chenopodiaceae are prominent.

Temperate grasslands occur in the corridor between desert areas and temperate forest in northern China and adjacent Siberia, and in small regions of Australia and in New Zealand. They occur where summers are warm to hot, and precipitation is between 250 and 500 mm/yr. Much of this may fall as snow. In Russia, China and Australia much of these areas have been converted into agricultural land.

In addition to the main types described above there are a number of vegetation formations which can be important habitats or centres of biodiversity, and these include the Mediterranean heaths and scrubs of southern Australia, the heaths of New Caledonia and northern New Zealand, marine meadows and saltmarshes, saline flats and mangrove systems. These are not shown in Fig. 3.

Extensive areas of vegetation on the PEP II transect have been modified by human activity. In many cases, such as in areas of degraded rainforest in tropical parts of the region, the process and effects of degradation are obvious. They are far less clear in other cases, however, for example in fire-adapted vegetation in Australia and in vegetation types on impoverished soils. In many cases, such land cover changes have exacerbated both chronic (e.g., severe erosion; Shi and Shao, 2000) and episodic (e.g., floods, landslides; Sidle et al., 1985; Yin and Li, 2001) hazards.

4. Human settlement patterns in Austral-Asia

Human settlement and impact across the region covers a huge range of situations (Fig. 4). The earliest known settlements are in the Yellow and Yangtze valleys of China, and these date from the early Pleistocene. The Longgupo site near Chongqing has the oldest known material, at close to 2 Ma, these, and Java 'Man' include material cultures comparable to contemporaneous material from Africa. Other famous sites from Java and Flores suggest humans were present between 800,000 or even at about 1 Ma. A number of migrations of these forms occurred between 400 and 300 ka when Peking 'Man' formed settlements in caves near Beijing. Modern humans (*Homo sapiens*) become widespread from about 20–25 ka across mainland Asia, and sites of 50 ka or more are now being found in Australia (Walters, 2002). Assuming the dates are correct, this can only have taken place with one or more major water crossings. It seems likely that at least two forms of hominids entered or even evolved in the region and that they may have cohabited until after 50,000 years ago. The debate surrounding the nature of these early dates and what they mean in terms of cultural and intellectual capacity is fuelled by speculation based on the small amount of evidence currently available. It seems reasonably likely that a Sundaland group of Mongoloid were ancestral to people in Oceania, a northern group dispersed through northeast Asia (Fig. 4) and via Beringia to the Americas.

In the late Pleistocene there is reliable evidence of humans in New Guinea, the Bismarck Archipelago and Australia, and by 20–25,000 years ago most major habitats in Australia were occupied. In the mid-Holocene the appearance of a whole new technology of microlithic tools possibly signifies a new migration from somewhere in Asia. In the last 1000 years or so new migrations into Australia from Indonesia and New Guinea are known.

Migrations into island Melanesia probably began at least 40,000 years ago, given the record in New Guinea (Van Dijk and Thorne, 2002), whereas migrations into Polynesia began from Melanesia after the mid-Holocene (Fig. 4). There is a view that Polynesian people were largely of southeastern Asian origin with some admixture with Melanesians picked up on their way to Polynesia. The archeological evidence has people in the Solomon Islands by about mid-Holocene time, then into Vanuatu, New Caledonia, Micronesia and Fiji from around 3500 BP. A large part of the story in the Pacific is based on Lapita pottery fragments, but in some cases it is supported by palaeoecological evidence of sustained vegetation disturbance and clearing for agriculture.

The story for New Zealand is different. It was settled comparatively late, perhaps about 800 years ago (Fig. 4). The reason is often stated to be its relative isolation and the fact that the boat people of the time had to sail against the westerlies to land there. Settlement on the Chatham Islands, east of New Zealand was perhaps as late as 400 years ago. Some island areas of the Pacific may have never been settled (e.g. Lord Howe Island) and others were possibly settled or at least visited and then abandoned (e.g. Norfolk Island).

Permanent human settlement across the region therefore has a complex history and a lot more research is required before the complete story unfolds. Each region has its own story of human impact but after settlement in each place comes the challenge of disentangling the relative impacts of natural variability and anthropogenic changes in interpreting the palaeoenvironmental records. In most regions populations started out relatively small and major impacts are revealed relatively soon where agriculture was established. Agriculture was surprisingly early in New Guinea, perhaps in the Late Pleistocene, and large scale impacts of agriculture are known from China in the early Holocene and later elsewhere. In Australia a hunter-gatherer society with a limited manipulation of ecosystems by fire many have been in existence for over 40,000 years, and agriculture was not established until European settlement of Australia about 200 years ago. Melanesian, Micronesian and Polynesian people migrated with sophisticated gardening and agricultural techniques and quickly established them in the new lands. As populations grew, or where pressure for land on small islands increased, so did the scale of human impact. The Ainu people in Hokkaido were basically a hunter-gatherer and trading society with limited use of agriculture, and the main impact on natural ecosystems there took place after Japanese colonization within the last century. In some places the human history story is sufficiently long and

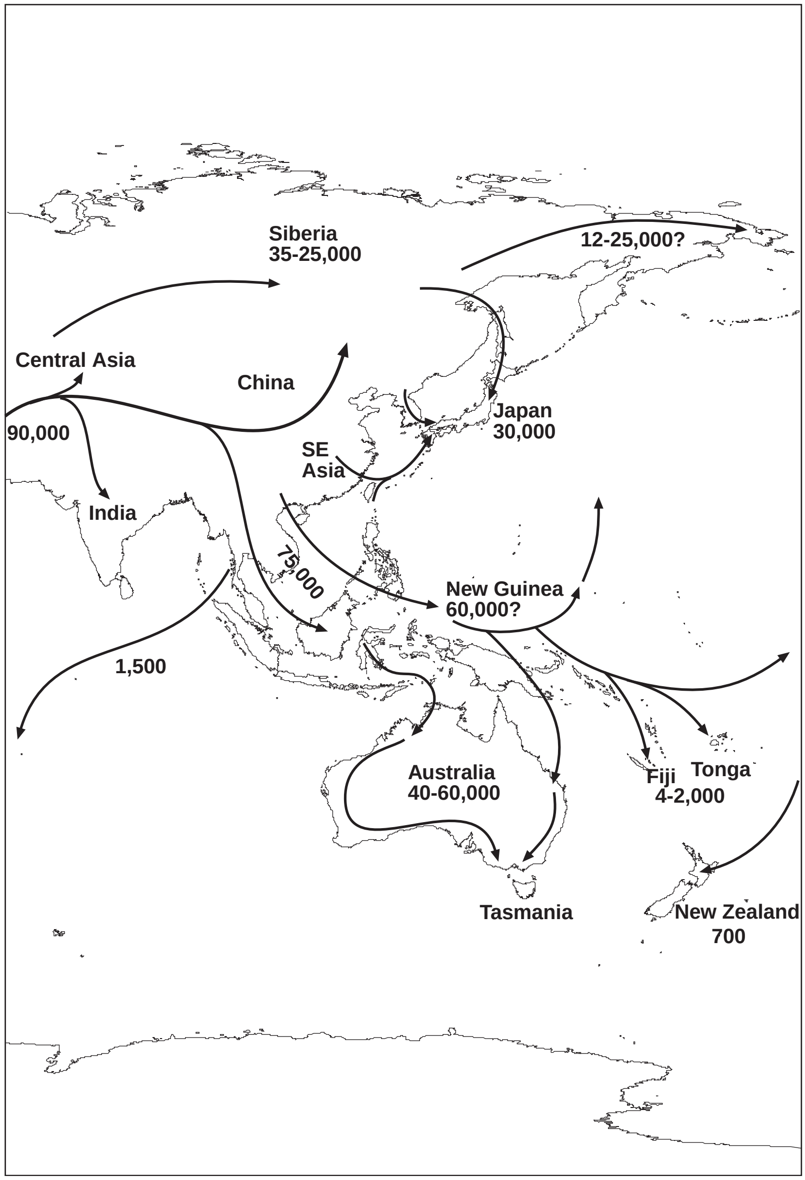

Fig. 4. Human settlement dates.

detailed to investigate how climate change affected early societies and the distribution of activity.

In modern times urbanization, forestry, broad scale agriculture and industry have brought ever greater impacts on terrestrial and marine ecosystems. The question now is not whether human activity or natural variability has the greatest influence on environmental systems; rather what are the consequences and feedbacks of human induced environmental change on environmental systems and societies themselves. The PEP II region contains a wonderful range of natural environmental systems to investigate a great variety of case studies of environment and human interactions.

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