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High Mountain Remote Sensing and Geology of the Central Andes – Remarks on an International Symposium held in Mendoza (Argentina)

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Argentina
Chile
Precordillera
Frontal Cordillera
Principal Cordillera
Remote Sensing
Geographic Information Systems
Geology
Geomorphology
High Mountain Ecology

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Hochgebirgs-Fernerkundung und Geologie der Zentralanden – Bemerkungen zu einem Internationalen Symposium in Mendoza (Argentinien)

Zusammenfassung

Das dritte Hochgebirgs-Fernerkundungssymposium (Symposium on High Mountain Remote Sensing Cartography; HMRSC-III) fand im November 1994 in Mendoza/Argentinien statt. Im ersten Teil der Arbeit werden die während des Symposiums gehaltenen Vorträge vorgestellt. Die Vorträge zeigten klar, daß die Ziele von kartographischen und geowissenschaftlichen Projekten in ausgedehnten Hochgebirgslandschaften nur durch die Kombination von Fernerkundungsmethoden mit anderen geowissenschaftlichen Untersuchungsmethoden erreicht werden können. Um qualifizierte und objektivierbare, das heißt wissenschaftlich nachprüfbare, Ergebnisse zu erlangen, muß dem ground check und der Zuordnung der digitalen Bildinformationen eine viel größere Bedeutung zukommen als bisher. Für integrierte, fernerkundungsgestützte geowissenschaftliche und geoökologische Projekte sind klein- und großmaßstäbige geologische, geomorphologische, pedologische, sowie klimatologische und hydrologische Geländeauswertungen in einem weit größeren Umfang als bisher erforderlich.

Im zweiten Teil dieser Arbeit wird eine kurze Beschreibung des geologischen Aufbaus der Anden zwischen Mendoza und der pazifischen Küste gegeben, welcher während einer Exkursion nach dem Symposium studiert werden konnte. Abschließend wir noch kurz auf den Stand der topographischen und geologischen Landesaufnahme Argentiniens eingegangen.

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Abstract

The 3rd International Symposium on High Mountain Remote Sensing Cartography (HMRSC-III) was held in Mendoza/Argentina in November 1994. The first part of the paper presents and summarizes the lectures given which showed clearly that the goals of cartographic and geoscientific projects in extended high mountain areas can only be reached by the combination of remote sensing techniques with other interdisciplinary methods. To obtain more qualified and objective results, much more time must be dedicated to the ground check and referenciation of the digital image information than commonly stated. For integrated remote sensing based geoscientific, and in particular geoecological, projects, small- and large-scale mapping of the geology, geomorphology, pedology, as well as climatological and hydrological investigations, are necessary to a much greater extent than presently undertaken. This understanding could cause a change of paradigm for further applied and integrated remote sensing projects.

In the second part of the paper a short description of the geological framework of the Andes from Mendoza to the Pacific coast, studied within the post-symposium field trip, is given. The final part concentrates on the state of geological and topographic mapping activities in Argentina.

Percepción remota y geología de los Andes Centrales – Anotaciones a un simpósio en Mendoza (Argentina)

Resumen

El tercer Simpósio Internacional de Percepción Remota en Cartografía en areas de alta montaña (HMRSC-III) se realizó en la ciudad de Mendoza, Argentina, entre el 7 y 13 de noviembre de 1994. En la primera parte de la presente publicación se exponen las conferencias que se dieron en el simposio, con resumen de su contenido. Las conferencias demostraron claramente que los objetivos de proyectos cartográficos y geocientíficos en amplias áreas de alta montaña no pueden ser logrados sino en base a la combinación de métodos de percepción remota con otros métodos geoscientíficos de análisis. Para obtener resultados objetivos y calificables que pueden ser revisados con métodos científicos hay que atribuir más importancia que hasta la fecha a la verificación en el campo y al proceso de georeferenciación de los datos digitales. Para realizar integrales proyectos geocientíficos y geoecológicos basados en la percepción remota se necesitan, más que hasta la fecha, conocimientos de campo geológicos de menor y mayor escala, geomorfológicos, pedológicos, climatológicos e hidrológicos.

La segunda parte presenta una breve descripción de la estructura geológica de los Andes entre la ciudad de Mendoza y la costa pacífica, estructura que pudo ser estudiada en trabajo de campo después del simposio. La parte final aborda el estado actual de las actividades de mapeo topográfico y geológico en Argentina.

1. Introduction

As announced previously (Häusler, 1993) the third "International Symposium on High-Mountain Remote Sensing Cartography (HMRSC-III)" took place in Mendoza/Argentina from November 7–12, 1994. The symposium was hosted by the Institute for Applied Research in Space Sciences (Instituto de Investigaciones Aplicadas de Ciencias Espaciales, IIACE) at the Regional Center of Scientific and Technical Research (Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET) in Mendoza City. The perfect organisation of HMRSC-III was done by Santurnino Leguizamón and his secretary Susana L. Arrieta (IIACE, Mendoza) who were supported by Claude Bardinet (Paris, France), Hubertus Bloemer (Athens, Ohio, USA) and Manfred Buchroithner (Dresden, Germany). The symposium was sponsored by the National Commission of Space Activities of Argentina (Comisión Nacional de Actividades Espaciales, CONAE), the European Space Agency (ESA, France), the Centre National d'Etudes Spatiales (CNES, France) and the U.S. Geological Survey.

The technical sessions were followed by a field trip from Mendoza across the Andean mountain chain to Santiago de Chile and Valparaiso and closed in Viña del Mar, at the Pacific coast, with a visit to the Oceanographic Institute of Valparaiso University. The purpose of HMRSC-III was, in the tradition set by the preceding symposiums at Schladming in Austria (1990) and Beijing and Lhasa in China (1992), to exchange experiences and ideas on inderdisciplinary remote sensing studies in high mountain areas and to promote these activities in Latin America.

Mendoza is situated about 1000 km west of Buenos Aires and 250 km east of the Pacific coast (Chile) at the eastern foot of the Andean mountain chain, at an altitude of 750 m. Due to its location in the southern hemisphere (69°W, 33°S) the participants of the symposium were able to enjoy the beautiful weather of the early summer season in november. The area around Mendoza shows arid climatic conditions, the total annual precipitation amounts to approximately 100 mm, and the humidity is around 2–3 %. In spite of this unfavorable climate the Mendoza valley is a kind of "oasis", well known for its vineyards producing wines of excellent quality. The water supply is guaranteed by an irrigation system, dating back to the ancient irrigation network of the Indios "aseccie", fed by melt waters of the Sierra de Paramillos glaciers in the Andes, at an altitute of approximately 3500 m. Due to the fact that Mendoza is surrounded by steppe and desert, the conservation of a local micro climate in Mendoza valley is of special importance to the local authorities. Mimosa and plane trees are planted under government supervision, with the target to plant one tree for each of the 880.000 inhabitants ("Por una ciudad en flor").

Apart from the constant battle against desertification, seismic risks have always been a major threat for the people of Mendoza. In 1866, 300 years after its foundation by Don Piedro del Castillo, the city was totally destroyed by an earthquake. Today's precautions like safety instructions in hotel rooms ("como actuar en caso de terremoto"), remarkably broad avenues and wide parks, so there would be no danger of being hit by collapsing buildings, reminded the participants of the symposium of this permanent georisk. How to react in the case of an earthquake is already taught in primary schools, using manuals published by the "Instituto Nacional de Prevención Sísmica". Like their ancestors, who protected their earthen wine casks against destruction by an encasement of iron rings fixed in the stone walls of the cellars, the present inhabitants of Mendoza are well aware of this permanent georisk.

2. Technical Session

The lectures given during the technical sessions of the HMRSC-III represented many different fields of remote sensing application and GIS, including topographic and thematic mapping in Europe (M.F. Buchroithner & N. Prechtel; R. Kostka) and Argentina (G. Ibañez & O. Peinado; V. Kaufmann & W. Klostius), glaciology and quaternary geology in Italy (M. Antoninetti et al.), in Argentina (R. Llorens & J. Leiva) and in Antarctica (J. Thomas). One major subject discussed during the congress were interdisciplinary studies dealing with remote sensing techniques as a useful tool for thematic mapping and environmental monitoring in the Himalayas and in Tibet (M. ANTONINETTI et al.; C. BARDINET et al., G. BAX; H. HÄUSLER et al.; D. LEBER et al.).

Further contributions about Argentina dealt with geological risks (M. DE SARQUÍS et al.; H. CISNEROS; R. RICHARDSON) as well as with geology and neotectonics (G. DE SALUMINI & G. SUIVIRES; R. LLORENS & H. CISNEROS; J. PERUCCA; G. SUIVIRES) and with geomorphology (W. SULZER).

N. BERNEX (Pontificia Universidad Católica del Perú, Lima) reported about the progress of remote sensing activities for environmental risk assessment and environmental classifications in Peru.

H. BLOEMER gave some general explanations about geobiophysical modelling of the biosphere and hydrosphere and about data acquisition and data exchange on a global scale. S. LEGUIZAMÓN reported on an attempt towards automatic pattern recognition of cartographic area features.

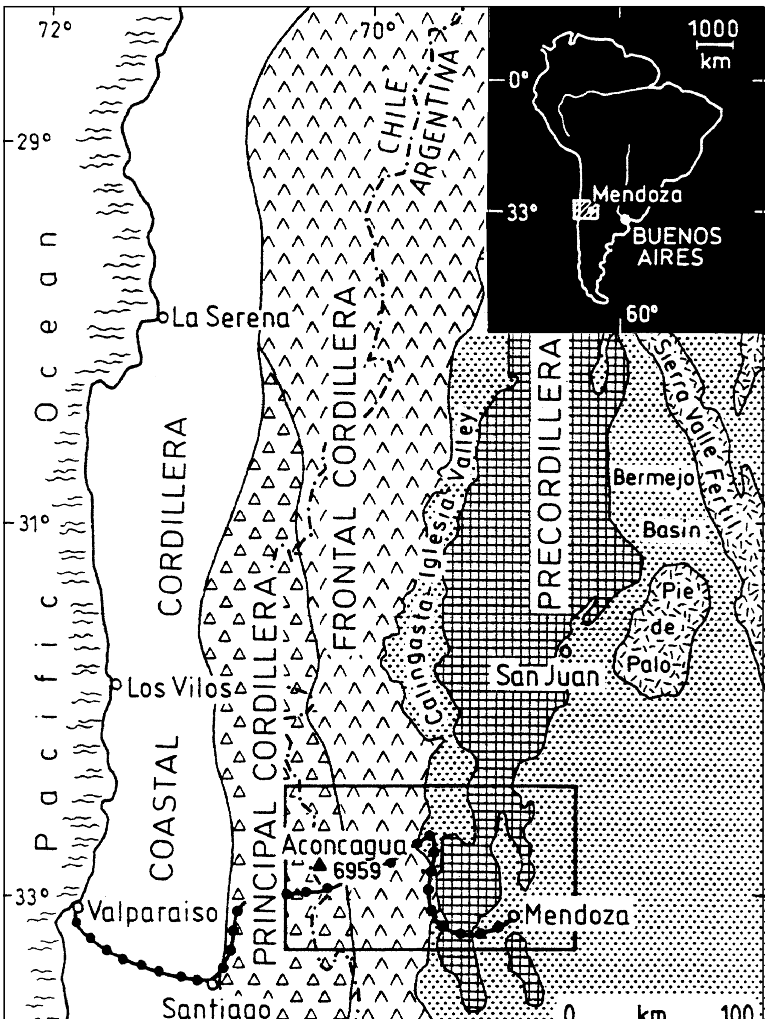
In special sessions of the HMRSC-III, J. LICHTENEGGER spoke about the European Space Agency's ERS missions and potentials and limitations for SAR (Synthetic Apertur Radar) data application in high mountain regions.

C. HERBAS gave a lecture about the activities of the Asociación Boliviana de Teledetección para el Medio Ambiente (ABTEMA) and R. LLORENS and J. LEIVA about the activities of the Instituto Argentino di Nivología, Glaciología y Estudios Ambientales (CRICYT).

The given lectures stressed the importance of the application of remote sensing techniques within interdisciplinary geoscientific studies in high mountain areas. Besides the opinion, stated by the participants of the HMRSC-III, that much more time must be dedicated to the ground check and referenciation of the digital image information than commonly stated, to obtain qualified and objective scientific results, the importance of the application of Digital Elevation Models (DEM) for the geocoding of the data sets of areas showing a pronounced topography was underlined.

On the last day of the technical session the participants of the symposium gained an idea of the manyfold activities of the Institute for Applied Research in Space Sciences (IIACE), which was founded in Mendoza in 1979. The main objectives of its scientific research are the evaluation of natural resources by remote sensing techniques, investigations in the field of non-conventional energy and the development of electronic products (e.g. construction of small pay load satellites). Closer contacts with Austria include a digital image processing project with the Technical University of Vienna (pattern recognition) and a visit of a delegation of the Austrian Science Foundation (FWF – Prof. E. RAUCH / Dr. E. GLÜCK) in 1993 (IIACE 1993).

Remote sensing application is an aspiring discipline in Latin America and in Argentina and Chile in particular for those who are interested in mineral exploration and mining. Basic investigations for this purpose are carried out by the geological surveys of the respective countries and by the Center for Inter-American Mineral Resource Investigations (CIMRI) belonging to the U.S. Geological Survey (B. EISWERTH).



Text-Fig. 1.
Morphotectonic provinces of Chile and Argentina between 29° and 33°S (modified after V. RAMOS, 1986: Text-Fig. 3).

3. Post-Symposium Excursion

The post-symposium excursion, guided by Santurnino LEGUIZAMÓN, covered the area from Mendoza mainly along the Mendoza valley to Uspallata, Punta de Vacas, Punte del Inca to Las Cuevas near the Chilean border, where the Central Argentine Andes culminate in the impressive Cerro Aconcagua (6959 m), the highest mountain in the Andes chain.

From there the field trip continued along the interstate road down the steep western slope of the High Cordillera to Santiago (Text-Fig. 1). After a short time for recreation and a visit to the scenic spots of the capital of Chile, the participants of the HMRSC-III proceeded to Viña del Mar, a lovely seaside resort on the Pacific coast, where the trip and the symposium ended with a visit to the Oceanographic Institute of Valparaiso University

The orientation in the field and the observation of geological and geomorphological features were facilitated by a satellite image map at a scale of 1 : 100.000, covering the area between Mendoza and the border, which was prepared by the U.S. Geological Survey (J. THOMAS, Reston, Virginia). The map was derived from a geometrically controlled and Laplace-filtered Landsat Thematic Mapper image acquired on April 27, 1986. It represents a valuable update to the topographic maps at a scale of 1 : 100.000, which are only available from the Instituto Geografico Militar (Buenos Aires), and date back to the year 1946 (!).

The Central Andes in the region between 30°S and 35°S are characterized by a significant narrowing of the mountain chain, resulting in the formation of high massifs. In particular the area between Mendoza and Santiago is known for important culminations like Mercedario (6770 m), Aconcagua (6959 m) and volcanoes like Tupungato (6650 m) and San Jose (6030 m).

Due to the fact that the region of the Sierra de Aconcagua massif is underlain by a relatively flat slab of the Nazca plate, which coincides with the presence of two aseismic ocean ridges at its northern (Juan Fernandez "hot spot traces") and southern boundaries (Easter Island – Sala y Gomez), the underlying plate geometry may be responsible for the distribution, altitude and shape of the mountain range and intervening trenches e.g. in the Río Mendoza drainage basin. This zone of low-angle subduction, which has eliminated volcanism for reasons that are not fully understood, but possibly involve crustal compression, has caused very high topography to develop along major faults.

The field trip offered an impressive insight into the complex geologic framework of the Andes. Although the 7500 km long, mainly North-South-striking mountain range appears geomorphologically uniform, its geological history is characterized by a temporal and spatial superimposition of different crustal sections since the Precambrian (W. ZEIL, 1979).

Between Mendoza in the East and the Pacific coast, two main tectonic units, the Precordillera terrane in the east and the Chile terrane in the west, including several morphostructural units, have been distinguished. The Precordillera terrane extends in the west to the Iglesias-Calingasta-Uspallata-Valley (V. RAMOS, 1988). The Chile Terrane is subdivided from east to west into the Frontal Cordillera, the Principal Cordillera (also termed High Cordillera) and the Coastal Cordillera (V. RAMOS, 1986; C. REGAIRAZ & J. ZAMBRANO, 1991; see Text-Fig. 1).

The geological history of the Andes started with the continental accretion of the allochthonous terrane Chilenia onto the western margin of Gondwanaland in early Palaeozoic (Famatinian orogenic cycle; Ordovician/Silurian). The Gondwanides orogenic cycle is characterized by the subduction of an oceanic plate beneath a continental margin during late Palaeozoic to early Mesozoic times. It was followed by the Patagonides orogeny during middle to late Mesozoic times. The Andean orogenic cycle (Incaic Phase: Paleogene; Quechua phase: Neogene and Diaguitic phase: Quaternary) is distinguished by atypical sections of the orogen that are controlled by the segmentation of the subduced oceanic Nazca plate to aseismic ridge subduction. The Andean orogeny shows a complex interaction between the subduction of aseismic ridges, with the segmentation of the Cordillera and the development of longitudinal changes in the geometry of the Benioff zones (see W. ZEIL, 1979). Nevertheless, diastrophic phases extend beyond the individual collided segments along thousands of kilometers.

The Precordillera northwest of Mendoza is an Andean thrust and fold belt that has been developed on early to late Palaeozoic sedimentary rocks. The Frontal Cordillera and the Coastal Cordillera (Chile) were built during the Gondwanides orogeny. The Principal Cordillera, or High Cordillera, is the result of the Patagonides and Andean orogenies during Mesozoic to Cenozoic times. The Andean mountain building phases also influenced the Sierras Pampeanas (Pampean Range east of Mendoza) as the Precambrian to early Palaeozoic basement rocks of the Precordillera show a set of imbricated overthrusts.

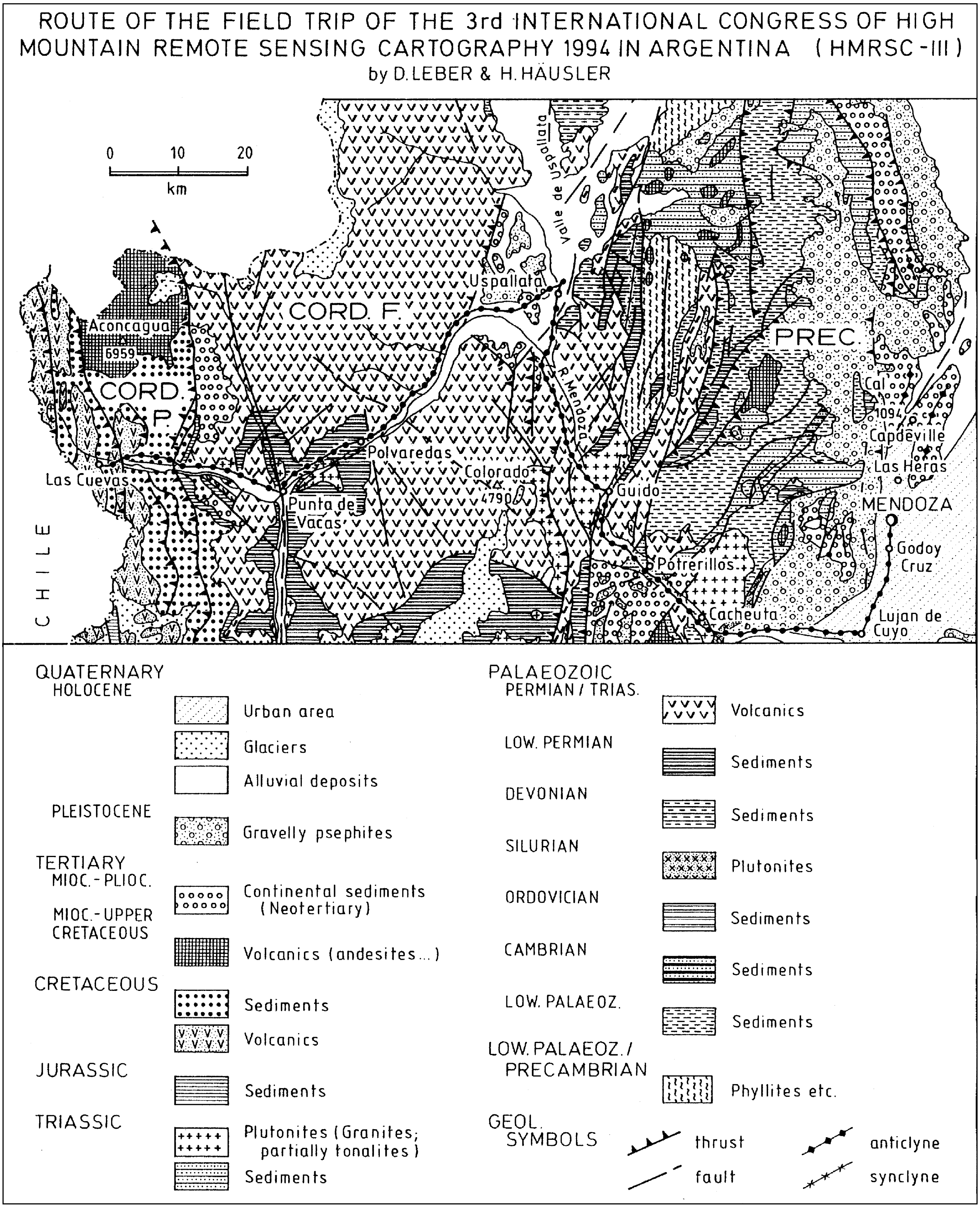
Besides the above mentioned complex tectonic processes, which led to a complete reworking of the geomorphology of the Andes mountain chain, erosional processes contributed to its present appearence and especially glacial processes in the Pleistocene as many authors have pointed out (e.g. F. REICHERT, 1910; C. CAVIEDES, 1972; C. CAVIEDES & R. PASKOFF, 1975; M. KUHLE, 1985, 1987; C. SCHUBERT & C. CLAPPERTON, 1990; J. RABASSA & C. CLAPPERTON, 1990; G. SELTZER, 1990; C. CLAPPERTON, 1993; L. ESPIZUA, 1993). Glacial deposits were observed by the participants of the symposium along the interstate road West of Puente de Vacas and in the area of Puente del Inca and near Cerro Aconcagua.

Mendoza is situated in the West of the Pampean Range, near the eastern foothills of the Precordillera. The eastern border of the Frontal Cordillera was uplifted during the Diaguitic phase (2 Ma). The Cerro La Cal section near Mendoza (V. RAMOS, 1988, Text-Fig. 14) represents the North-South-striking geomorphological front of this quaternary orogenic phase. The late Miocene and Pliocene deposits of the Uspallata and Cacheuta regions were folded and thrust eastwards during the Pleistocene. Even the Pleistocene fanglomerates of the Mogotes formation, cropping out west of Mendoza city and younger alluvial fans have been deformed by neotectonic activity.

The route of the post-HMRSC-III field excursion (Text-Fig. 2) crossed the western rim of the stable San Raffael (Gondwana) block, to the south of Mendoza, which is imbricated at the eastern foothills of the Precordillera in Cerro La Cal and the adjacent plains around the city. The urban area between Mendoza, Godoy Cruz and Lujan de Cuyo is located on Quaternary and Holocene deposits, overlying flat Palaeozoic to Mesozoic formations. All these piedmont areas in Mendoza province show the footprints of neotectonic movements especially of Pliocene to Pleistocene age (C. REGAIRAZ, 1985). West of the village Lujan de Cuyo the interstate road follows the Río Mendoza upstream. The Precordillera in this section is mainly built up of Permian volcanic rocks (andesites) and granites of lower Triassic age and Triassic continental sediments.

The village of Guido is situated on Triassic granitoides which intruded Precambrian to Lower Palaeozoic phyllites, greywackes and metagabbros. Near the bend of the Río Mendoza Permian dacites and rhyolites crop out. Southwest of the broad neotertiary Uspallata valley (1750 m; 100 km West of Mendoza) the road crosses the Quechua orogenic front (10 Ma) of the Frontal Cordillera, which extends westward to the village Puente del Inca. The Frontal Cordillera is characterized by sedimentary, volcanic and plutonic rocks belonging to a pre-Jurassic basement complex. Between the villages Polvaredas and Punta de Vacas a North-South-trending anticline is made up of Carboniferous deposits and Permian granitoids. In the valley of the river Río de Las Cuevas near Puente del Inca (2700 m) the westward dipping Palaeozoic of the Frontal Cordillera is overthrust by slices of the Principal Cordillera in eastern direction.

The Puente del Inca section offers a superb and impressive insight into the compressive tectonics of the final stage of the Patagonides cycle from Jurassic to Creta-



Text-Fig. 2.
Geology of the area between Mendoza and the Chilenian border with route of excursion, modified after SECRETÁRIA DE INDUSTRIA Y MINERIA (1964) and SECRETÁRIA DE MINERIA DIRECCION NACIONAL DEL SERVICIO GEOLÓGICO (1993).
PREC = Precordillera; CORDF = Frontal Cordillera (Cordillera Frontal); CORDP = Principal Cordillera (Cordillera Principal).

ceous time. Folded Jurassic formations were thrust along the Auquilco gypsum beds. These slices of the Principal Cordillera are discordantly overlain by Upper Cretaceous to Miocene andesitic volcanites (W. ZEIL, 1979). The Cerro Aconcagua (6959 m) is built up by volcanites of the Abanico formation of Upper Cretaceous (Campanian and Maastrichtian) to Lower Tertiary age (R. CAMINOS, 1979; M. YRIGOYEN, 1979). Puente del Inca is famous for its thermomineral sulfur springs (38°C) which have stained the Jurassic limestones of the ancient spa a yellowish to brownish colour. The name Puente del Inca recalls the fact that the empire of the Incas once extended far across today's Mendoza province.

The Río Mendoza valley continues for some 120 km west of Mendoza in the Aconcagua region of the Cordillera Principal. The river follows an antecedent valley incised into the Cordillera Frontal (in the East) and Cordillera Central (in the West).

The river begins as the Río Horcones at the foot of Cerro Aconcagua on its southeast side. The southern face of Aconcagua consists of a series of stepped cliffs with slabs of glacier ice above the Horcones Glacier (Text-Fig. 3).

Uranium-series dating of travertine deposits, mantling moraines in the upper reaches of the Río Mendoza valley east of Aconcagua, suggest that they were deposited at ca. 20.000 years BP (C. CLAPPERTON, 1993).

Using relative age criteria of terminal moraine deposits the following different drifts have been named (youngest to oldest, from West to East): Confluencia stage, Almacenes stage, Horcones stage, Penitentes stage, Punta de Vacas stage and the Uspallata stage, some 50 km farther downstream (C. CLAPPERTON, 1993; L. ESPIZUA, 1993).

Possibly due to the tectonic uplift of the Aconcagua region of about 24 mm per year (C. CLAPPERTON, 1993), which is compatible with the tectonic uplift of marine terraces along parts of the Chilean coast (U. RADTKE, 1991), the snowline East of Aconcagua was raised in the Quaternary.

To summarize, the following five morphostructural units were observed during the excursion in Argentina from East to West (C. REGAIRAZ & J. ZAMBRANO, 1991):

1) The Eastern Mendoza Plain is a flatland with very gentle slopes and altitudes between 750 m at the piedmont edge and 450 or 500 m at the Eastern boundary of Mendoza province. These plains are built up by 300 m to 1000 m thick Quaternary continental sediments.
2) The Piedmont Hills, which are low mountains or hills with altitudes from 800 m to 1200 m are built of folded and faulted continental Tertiary deposits, affected by arid fluvial processes. They are made up by 3 Pleistocene pediment surfaces, 2 Pleistocene terraces, 1 or 2 Holocene terraces, and alluvial fans. The most important fan, the one of Mendoza river, extends over a surface of 500 km^2.
3) Mendoza's Precordillera, which consists of Palaeozoic marine sedimentary rocks and continental Tertiary deposits, at altitudes between 1000 m to 3000 m, was affected by periglacial processes in their higher zones and by arid fluvial erosion at lower or medium altitudes.
4) The geomorphology of the Frontal Cordillera, which consists of Precambrian to Early Palaezoic metamorphics, Palaeozoic marine sediments and Permotriassic sequences, at altitudes from 4000 m to 5000 m, was mainly modelled by Quaternary glaciations.
5) The Main, or Principal (also Central) Cordillera, which lies at an altitude between 5000 and 7000 m and consists of marine and continental sedimentary and volcanic rocks of Jurassic, Cretaceous and Cenozoic age, resting upon a Permotriassic basement, was strongly affected by Quaternary glaciations.

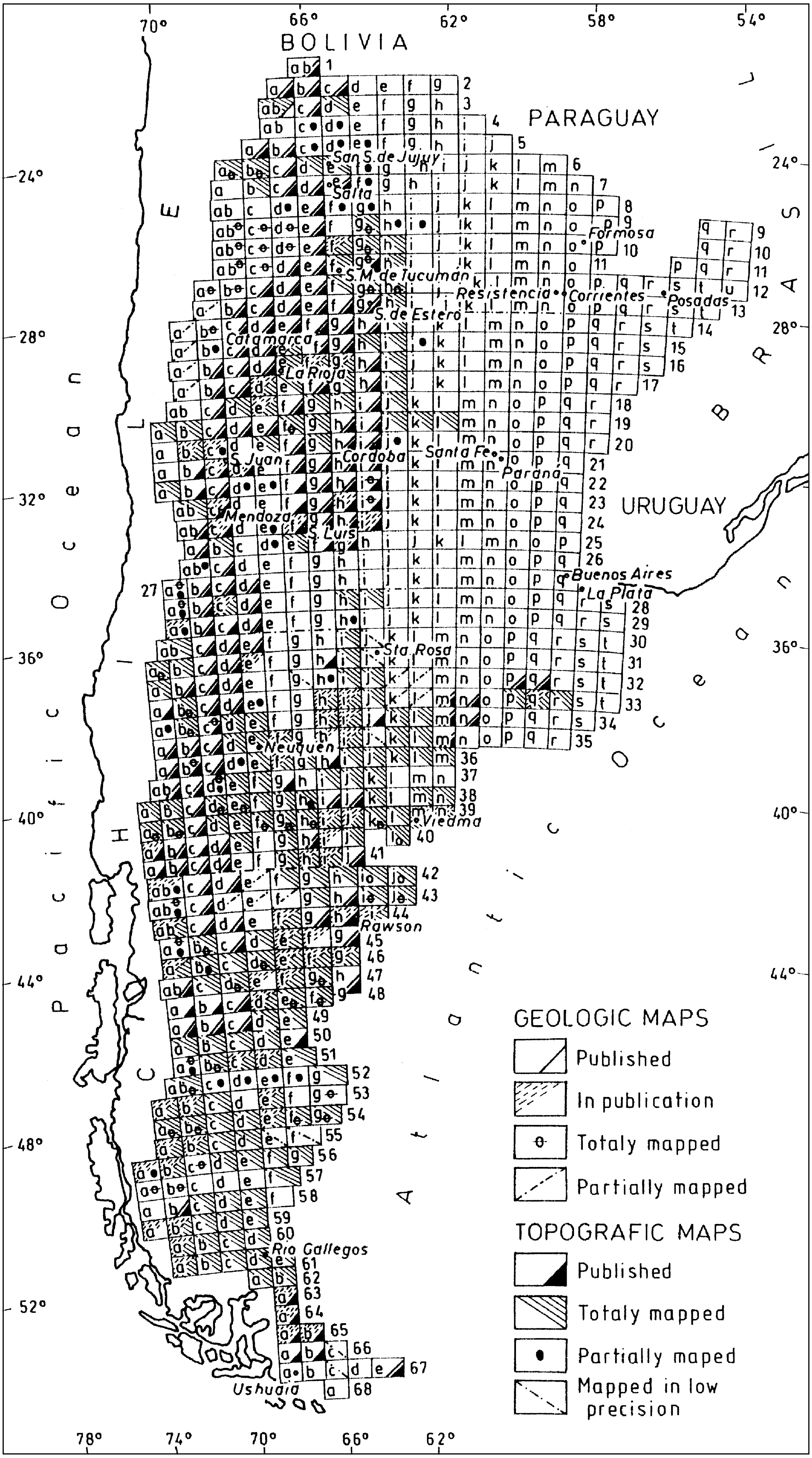
Text-Fig. 3.
Hummocky deposits of the Horcones moraine near the eastern base of Cerro Aconcagua (6959 m) in the upper part of the Río Mendoza drainage basin. The partly shaded ridge in the middle distance is the Almacenes moraine, which may be of Late-glacial age.

4. Present State of Topographic and Geologic Mapping in Argentina

Although the territory of Argentina covers an immense area of 2,766.889 km² (W. Waldmann & H. Krumwiede, 1992; World Bank, 1993), and the large western part it characterized by the pronounced topography of the Andes mountain chain, with some nearly inaccessible areas, the topographic and geological mapping is in an advanced stage.

4.1. Geodetic and Topographic Survey

The geodetic and topographic survey of Argentina is being carried out by the Instituto Geográfico Militar (IGM), Buenos Aires (Avenida Cabildo 301, 1426 Buenos Aires). A Gauss-Krüger conformal cylindrical projection is being used, and the territory has been subdivided into seven, 3° longitude wide, zones. Up to now the following topographic maps at different scales are available, although the availability to the public is restricted for large scale maps.



Text-Fig. 4.
Present state of geological mapping of Argentina at a scale of 1 : 200.000, based on an old series of topographic maps at the same scale (after Servicio Geológico Nacional).

General maps

– República Argentina, 1 : 10,000.000, Buenos Aires, IGM, 1981.
– República Argentina, 1 : 5,000.000, Buenos Aires, IGM, 1980.
– República Argentina, 1 : 2,500.000, Buenos Aires, IGM, 1986.

Topographic maps

– Carta topográfica de la República Argentina, 1 : 500.000, Buenos Aires, IGM, 1939 70 sheets (all published).
– Carta topográfica de la República Argentina, 1 : 250.000, Buenos Aires, IGM, 1951 231 sheets (approximately 90 published).
– Carta topográfica de la República Argentina, 1 : 100.000, Buenos Aires, IGM, 1911 1900 sheets (approximately 715 published).
– Carta topográfica de la República Argentina, 1 : 50.000, Buenos Aires, IGM, 1906 7197 sheets (approximately 1710 published).

Maps at a larger scale are to a certain extent available for areas of special interest; for example, urban areas are available at a scale of 1 : 25.000.

4.2. Geological Survey

The Servicio Geológico Nacional (SGN), Buenos Aires (Avenida Santa Fe 1548, 1060 Buenos Aires), founded in 1963, is in charge of the mapping and publication of different kinds of geologic maps. The main activities are done at a scale of 1 : 200.000, based on an old series of topographic maps at that scale. A summary of the available maps is given below. Text-Fig. 4 shows the present state of geological mapping of Argentina at a scale of 1 : 200.000, based on the above mentioned old series of topographic maps.

– Mapa geológico de la República Argentina, 1 : 5,000.000, Buenos Aires, SGN, 1964.
– Mapa geológico de la República Argentina, 1 : 2,500.000, Buenos Aires, SGN, 1982.
– Carta geológica-económica de la República Argentina, 1 : 200.000, Buenos Aires, SGN, 1970, 700 sheets (approximately 25 % published).
– Mapa hidrogeológico de la República Argentina, 1 : 5,000.000, Buenos Aires, SGN, 1963.
– Mapa geotécnico de la República Argentina, 1 : 2,500.000, Buenos Aires, SGN, 1978.
– Mapa metalogenético de la República Argentina, 1 : 2 ,500.000, Buenos Aires, SGN, 1970.

Some geological maps, which were prepared for special occasions, are available at other scales e.g. the Mapa Geológico de la Provincia de Mendoza Republica Argentina, 1 : 500.000. Additionally a metallogenetic map of the Argentinian-Chilenian border area (Mapa Metalogénico de la Frontera Argentino-Chilena entre los 22° y los 34° de latitud sur) was prepared and published in 1994 by a joint working group of the Geological Surveys of Argentina and Chile.

5. Concluding Remarks

The environment of South America changed dramatically between and during glacial and interglacial intervals, in response to natural fluctuations in the earth's physical system. The impact of humans is a new variable which has emerged during the present interglaciation and which has caused widespread environmental changes, leading to a much faster rate of transformation, than is normally achieved by the natural environment (C. CLAPPERTON, 1993). To analyse these interrelationships between natural and man-made environment for a future benefit should be one major aim of modern geoscientific studies, including remote sensing techniques.

The 3rd International Symposium on High Mountain Cartography in Mendoza/Argentina will not be the last meeting of this type. Gerhard BAX (University of Karlstad, Sweden) agreed to promote and host the next symposium. The technical session of HMRSC-IV will be held in Karlstad and the post-symposium fieldtrip is planned to start in Karlstad and continue to Kiruna in northern Sweden and finish in Tromsö in the area of the marvelous fjords in northern Norway.

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