創立70周年記念出版
70th Anniversary of Foundation

大震災に学ぶ

——阪神・淡路大震災調査研究委員会報告書——

Lessons from the Hanshin-Awaji Great Earthquake Disaster

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The Kansai Chapter of Japan Society of Civil Engineers

発刊にあたって

平成７年１月17日午前５時46分に発生した阪神・淡路大震災は、近代では我が国最大の都市直下地震であったため、阪神間を中心に極めて甚大な被害をもたらしました。被災された多くの方々には、改めてお見舞いを申し上げます。

今回の大地震では、これまで我々がつくり上げてきた道路、鉄道、港湾等といった都市基盤施設の脆弱な部分を見せつけられ、土木技術者としてこの大震災を極めて重大かつ厳粛に受けとめなければならないことを痛感しました。

土木学会関西支部は震災の地元でもあり、全力を挙げて震災の復旧と復興に寄与したく、地震発生直後に『阪神・淡路大震災調査研究委員会』を組織し、この調査研究委員会を最重要の委員会活動と位置づけ、調査研究期間を３年間として、８つの分科会を設置しました。本調査研究委員会では、土木学会会員のみならず広く会員以外からも専門分野の人材を集め、地震被害の事実を正確かつ詳細に記録するだけでなく、その原因や発生のメカニズムの解明と対策の立案など、今後に踏み込んだ調査や研究を行ってきました。

平成９年度で関西支部は創立70周年を迎え、「大震災を越えて、土木文化の華を咲かそう」をメインテーマとし、21世紀を迎えるにあたっての土木のあり方、支部活動のあり方を議論すべく、各種の記念事業を行ってきました。この記念事業の一環として、本調査研究委員会活動の成果を詳細に取りまとめた報告書を出版することとしました。

阪神・淡路大震災は、土木技術のあり方を原点に戻って見直す機会を与えてくれたともいえます。この報告書がこれからの土木技術の発展に役立つとともに、大震災という貴重な教訓を風化させることなく、後世に伝えていく資料となれば幸いです。

終わりに、本報告書をとりまとめるにあたり、ご尽力いただいた皆様方に深く感謝の意を表します。

平成10年６月

(社)土木学会関西支部

支部長　足立　紀尚

支部創立70周年記念事業実行委員会

委員長　佐々木　伸

はじめに

土木学会関西支部
阪神・淡路大震災調査研究委員会
委員長　京都大学　工学部
土岐 憲三

阪神・淡路の大震災では危機管理の欠如が各方面で問題とされたが、この地震の前には研究者の間においても、大地震時に各研究者がどのような対応をすべきか、学会などがいかなる活動をするか、などに関して格別の方策が論じられることもなく、何らかの対応策が用意されているわけでもなかった。こうした状況下において、地震発生の当日やそれ以後の数日間も各研究者がそれぞれに独自の対応をしてしまい、組織だった活動は見られなかった。特に関西の研究者は地元の新聞社、テレビ局などとの対応に迫られ、数日間は拘束されたりしたりもした。

そのうち、土木学会の本部では震災調査団の派遣が検討され、当時の中村英夫学会長を団長とする第一次の調査団が現地に派遣された。学会本部では当時の耐震工学委員会（現：地震工学委員会）のメンバーもそれぞれの関係する分野での対応に追われて、委員会としてのまとまった活動が取れないでいた。このように、耐震工学や地震工学を専門とする研究者たちは、日々の対応に追われて互いに連絡取れないままに、打ちすぎるという状態が続いていた。

こうした状況下で、当時の土木学会関西支部渡辺英一幹事長は、被災の地元である関西支部も何等かの活動をすべきと考え、特別委員会を設置した。そして筆者に委員長として内容と陣容の編成の依頼があった。前述の土木学会の調査団以外にも多くの団体が被害調査のためのチームを派遣していたが、いずれも被害の実状を調査するためのものであり、被害に関しての一次資料の収集に重きを置いたものであった。関西支部は被災の地元でもあり、一次資料にしてもその収集に地元の地の利を発揮することが可能でもあり、さらに詳細な資料やある程度の加工や解析を施した二次資料については、もっと後になって提供されるであろうことから、単なる被害調査のみならず、被害資料に基づく研究にまで踏み込んだ調査研究を目標とするのが望ましいであろうとの結論に達した。こうした目的を達するためには時間を要することから、委員会の設置期間は平成７年２月から平成10年３月までの３ヶ年となった。

委員会で調査・研究の対象とする範囲は地震と土木をキーワードとする全ての事象を対象とすることになり、以下の８つの分科会を設け、以下のような陣容でスタートした。

委員長	土岐憲三（京都大学工学部）
副委員長	松井　保（大阪大学工学部）
幹事長	家村浩和（京都大学工学部）
地震活動分科会	尾池和夫（京都大学理学部）
地盤・基礎分科会	松井　保（大阪大学工学部）
鋼構造分科会	福本唀士（福山大学工学部）
コンクリート分科会	藤井　学（京都大学工学部）
	小野紘一（京都大学工学部）平成９年10月より
地下構造物分科会	桜井春輔（神戸大学工学部）
ライフライン分科会	亀田弘行（京都大学防災研究所）
緊急対応分科会	林　春男（京都大学防災研究所）
復旧・復興分科会	黒田勝彦（神戸大学工学部）

各分科会には幹事を置き、分科会長および幹事で構成される幹事会により、分科会間の連絡調整を行うこととなった。幹事会は平均して３ヶ月に１回の割合で開かれ、通算の開催回数は13回に達した。また、分科会の開催回数は延べ110回を超えている。

それぞれの分科会には多くの研究者や技術者が参加しており、中にはコンクリート分科会のように100

名を超える委員を擁するものもあり、その総数は最終年度には250名に達している。まさに関西支部を挙げての大調査委員会となったのである。

この委員会は他の機関や学会による調査団とは違って、その主目的を被害資料に基づく実験や解析による研究に置いており、これまでに２回の報告会と１回の講習会を開いて、委員会としての研究の成果を会員及び一般に対して報告している。すなわち、

○阪神大震災調査委員会報告
日　時：平成７年５月20日
場　所：立命館大学びわこ・くさつキャンパス
参加者：200名

○「耐震地震防災の基礎」講習会
日　時：平成７年12月８日
場　所：大阪市建設交流館
参加者：151名

○阪神・淡路大震災調査研究委員会中間報告会
日　時：平成８年９月５－６日
場　所：インテックス大阪国際会議ホール
参加者：470名

委員会の終了時には報告会を開催するとともに、その成果を関西支部の70周年記念事業の一環として出版することとなった。したがって、当該委員会の報告書は関西支部による阪神・淡路大震災に関する研究の成果として位置づけられることになり、委員一同の責任は重大なものとなった。

阪神・淡路大震災では多大の人的・物的被害を強いられたが、それと引替えに得た教訓も多い。こうした教訓を後世に誤りなく伝えることは我々の責務である。社会問題としては各界における危機管理体制の欠如、防災行政の観点からは要請主義の弊害などが取り挙げられたが、技術の面では内陸の活断層に対する考えが変わりつつある。また、これまでの仕様設計から性能設計への転換も進みつつあるが、これも技術の分野における阪神・淡路大震災による被害から得た教訓の一つであろう。こうした教訓の多くが本報告書の随所に取り入れられており、各分野における最新の動向を知ることができるものとなっている。

地震災害に関する研究や技術開発の成果は、設計の指針や基準に用いられることではじめて所期の目的を達することになるが、国や自治体などの行政の側も神戸の地震を契機として、新しい考えや技術を積極的に取りいれて行こうとする方向に転換しつつある。このような傾向は大変望ましいことであり、技術者や研究者が新しい研究や技術開発を行おうとする意欲を掻きたてることに結びつくものである。この報告書がこうした時代の変化を先取りしたものであり、かつ一層押し進めることに資することを期待するものである。

Lessons from the Hanshin-Awaji Great Earthquake Disaster
—The Report of the Research Committee on the Hanshin-Awaji Great Earthquake Disaster—
The Kansai Chapter of Japan Society of Civil Engineers

ABSTRACT

The Hyogo-ken Nanbu Earthquake which occurred on the 17th of January 1995 caused significant damages of civil engineering structures and urban disasters in Hanshin and Awaji areas in Japan. The Kansai Chapter of Japan Society of Civil Engineers established the Research Committee immediately after the earthquake. Total number of the Research Committee members is 250 and the committee consists of 8 Sub-committees chaired by following professors.

Chairman Professor Kenzo Toki (Kyoto University)
Vice Chairman Professor Tamotsu Matsui (Osaka University)
Secretary General Professor Hirokazu Iemura (Kyoto University)
Sub-Committee 1 for Seismic Activities
Chairman Professor Kazuo Oike (Kyoto Univeresity)
Sub-Committee 2 for Soil and Foundation
Chairman Professor Tamotsu Matsui (Osaka University)
Sub-Committee 3 for Steel Structures
Chairman Professor Yuhshi Fukumoto (Fukuyama University)
Sub-Committee 4 for Concrete Structures
Chairman Professor Manabu Fujii (Kyoto University) until Sept. '97
Professor Kouichi Ono (Kyoto University) from Oct. '97
Sub-Committee 5 for Underground Structures
Chairman Professor Shunsuke Sakurai (Kobe University)
Sub-Committee 6 for Lifelines
Chairman Professor Hiroyuki Kameda (Kyoto University)
Sub-Committee 7 for Emergency Response
Chairman Professor Haruo Hayashi (Kyoto University)
Sub-Committee 8 for Reconstruction and Restoration
Chairman Professor Katsuhiko Kuroda (Kobe University)

The summaries of the reports from the 8 sub-committees are shown below. It is author's strong hope that serious lessons learnt from the Earthquake Disaster would gives us invaluable benefits to improve seismic safety of urban areas against future strong earthquakes.

Part 1 Seismological Characteristics of the 1995 Hyogo-ken Nanbu Earthquake

Seismicity in and around the epicentral region is described based on the newly edited data base of historical earthquakes and seismological data by Japan Meteorological Agency. Seismic active period of intraplate earthquakes along active faults in the Inner Zone of southwestern part of Honshu island, Japan begins about 50 yesrs before the interplate earthquakes along the plate boundary of Philippine Sea plate.

A clear surface fault system appeared along the pre-existed Nojima fault in the northwestern part of Awaji island. This system has been studied to clarify the recurrence interval, slip rate, slip

amount per one event, slip distribution along the fault, type of faulting etc , based on many methods such as photo- and map-interpretation, field obverbation, and trench excavations. The cumulative displacement and subsurface structure of the Nojima fault system are also surveyed by the deep drillings of all-core type and seisimic reflection studies.

The fault plane of the Hyogo-ken Nanbu Earthquake, which is almost vertical, strikes in the NE-SW direction. The rupture initiated at the depth of about 16 km beneath the Akashi strait, and it propagated bilaterally on the fault, toward Awaji-shima and Kobe. The total duration of rupture is about 12 s. The area with slips is shallower than 20 km, and the length of the area is 40-50 km. The amount of slip is heterogeneous on the fault. The peak slip of about 3 m occurred at the shallow part beneath the Nojima fault. The secondarily significant slip occurred beneath Kobe, which is dominant at deep depths. This precise picture of the source process was carefully determined by many researchers using different methods and datasets. Nevertheless, the broad picture can be obtained even in the analysis that can be automatized, which was shown for the Hyogo-ken Nanbu Earthquake using the recordings from the strong-motion instruments. This implies that for a large earthquake in the future a picture of the source process can be obtained in an automatic and rapid system quickly after the occurrence by connecting with quick data collection from strong-motion instruments.

Three-dimensional geometry of the faulting process of the 1995 Hyogo-ken Nanbu Earthquake is estimated from the strong-motion waveforms and static displacement data observed at near distances. The space that covers the aftershock area is divided into small blocks with a size of 4x5x2 km. The time resolution is assumed to be 1 sec in the source time function. A linear inversion is used to know the space-time image of the fault geometry and moment release. The fault in the Awaji Island dips to SE but the fault in the city of Kobe dips to NW. Major moment release concentrates in the NE part of the Awaji Island at depths of about 5 km. The discontinuities of faults show up in both Awaji and Kobe.

The 1995 Hyogo-ken Nanbu Earthquake struck Kobe City and its surrounding, heavily populated areas, the Hanshin district, Japan, killing more than 6,400 people and destroyed more than 150,000 buildings. Such heavy damage was caused by strong ground motions. This study reports why such destructive motions were generated to buildings and bridges. Two problems are discussed: where are the causative faults that generated the destructive ground motions? and why are the heavily damaged zones in Kobe not consistent with the surface fault traces associated with the buried faults? The near-fault ground motion in Kobe was characterized by two large long-period (1 to 2 seconds) pulses caused by forward rupture directivity. We confirmed that at heavily damaged sites such large long-period pulses were further amplified due to the basin edge effects from the 3-D simulation by the finite difference method.

Part 2 Investigation Report on Seismic Damages of Geotechnical Engineering Structures

This report describes the investigation studies made by the Sub-committee for Geotechnical Investigation on the seismic damages of various geotechnical structures due to 1995 Hyogo-ken Nanbu Earthquake. The main objective of this study was to examine the relationship between the geotechnical condition and the seismic damages of structures that are distributed over a wide area of Hanshin District. In Chapter 3 to Chapter 7 of this report, the seismic damages related to geotechnical engineering problems are described and the causes of damages were investigated by dividing the structural damages into 9 categories (i.e., slope instability, damages of residential housings, near-shore reclaimed lands, river embankments, harbor quay walls, road and railway embankments, underground pipes and conduits, water retaining earth fills, and foundation structures). The recovery schemes from damage were also described. Discussions on the cause of damage are made by shedding the light on the problems of ground liquefaction and also on the relationship between the degree of damage and the intensity of seismic motion.

Part 3 Damage of Steel Structures, Restoration, Retrofit and Design Methods

Established in the Sub-committee of Steel Structures chaired by Professor Y. Fukumoto and consisting of 36 members were five Working Groups for the survey and investigation on evaluation of seismic performance, strengthening methods, assessment of damage, causes of damage, and seismic design. Damage to steel highway bridges due to the Hyogo-ken Nanbu Earthquake, causes of the damage, and seismic design methods for steel bridge structures are intensively investigated in the work of this subcommittee.

Main conclusions in the subcommittee are as follows:

(1) Serious damage to bridge superstructures was subsequently caused by bearing and pier failures. Rational seismic design methods for bridge bearings and piers are necessary in the future.

(2) Methods for repair and strengthening of the damaged members in steel bridges are surveyed and summarized. Criteria to select suitable repair and strengthening methods, evaluation methods for repaired and strengthened members, and residual lifetime of repaired structures should be investigated.

(3) Causes of damage to structural members in urban elevated bridges due to the earthquake are assessed, and the relationship between the seismic behavior of bridges as a structural system and the damage to each structural member is investigated through practical examples. Systematical evaluation of the seismic performance of bridges as a structural system is an important subject to be investigated.

(4) Causes of damage of long, large and special bridges are investigated through numerical simulation of practical examples. Damage of paint due to the cyclic loading of plastic strain and occurrence of brittle cracks at the locations of stress concentration are also investigated.

(5) Points on seismic design to be learned through damage due to the earthquake, and the state-of-the-art of seismic design methods after the earthquake and strengthening method of the existing structures are investigated and summarized. It is necessary to investigate seismic design methods for steel structures as a structural system.

Part 4 Damage of Concrete Structures, Restoration, Retrofit and Design Methods

The sub-committee for concrete structures consists over 50 aggressive researches and engineers and have studied the damaged concrete structures, particularly viaducts of Hanshin expressway and Shinkansen. They are divided into 3 task groups.

In TG 1, data collections such as the completed year, types of columns and foundations, size of the cross-section, level of damage have been done for each pier. The level of damage is judged by the engineers of the sub-committee, mainly by looking at the damaged structure directly. Data of over 1,300 piers are collected. They are databased including the picture of each damaged structure. They are expected to be utilized in the future study. Various structural models to analyze the seismic response of bridge piers have been discussed. Although 3-dimensional models to represent a whole viaduct should be employed, the study has been done using a partial model of a viaduct.

The study includes non-linear analysis of a 3-span continuous viaduct including the effect of the bearing shoes, evaluation of shear capacity of columns and upwards impact effects to a pier. These analyzed results are compared with the corresponding damages in the actual viaduct. Damages of viaducts are also expressed by probability estimates.

In TG 2, for the purpose of improving present seismic design, a survey of various seismic design standards including those from abroad is performed to improve the present seismic design method. The difference among these standards is clarified by trial design of a representative pier using these standards. The concept of ductility is also discussed, in relation to the design of piers of the railway and highway. Furthermore, relation between the fracture mode of a pier and the material' s strength, shear strength capacity of the concrete and the displacement by shear is discussed. These discussions are expected to develop more rational seismic design of reinforced concrete bridge piers.

In TG3, evaluation of the damage and the repair method corresponding to the damage are discussed. Occurrence of various types and levels of damage in piers is pointed out although they are designed and constructed in the same way. Magnitude of the tremor and characteristics of the ground are mainly responsible for the difference. "Guideline of repair and restorations of damaged concrete structures" is proposed.

Part 5 Underground Structures are Safe for Earthquake!?

In general, the damage of underground structures due to the 1995 Hyogo-ken Nanbu Earthquake was very slight compared to extensive damage to surface facilities. It can be stated that underground structures are generally considered relatively safe from seismically induced damage.

It was a shock to civil engineers, however, a failure of a cut-and-cover underground metro station did occur. It is the first instance of severe damage to a modern tunnel for reasons other than fault displacement or instability near the portal. The most prominent damage concentrated at the center reinforced concrete columns of the stations and running tunnels. A detailed reconnaissance survey was conducted at the Daikai subway station.

The sub-committee for underground structures has investigated the reason why the metro stations failed and how the seismically-induced damage would be predicted, minimized and even avoided. The detailed data of damaged and not damaged underground structures were collected and analyzed carefully. All the earthquake resistance designs for underground structures were reviewed and evaluated against the level of Hyogo-ken Nanbu Earthquake.

We now have confidence that if the appropriate methods of analysis and design are provided, much of the observed phenomena and effects could have been predicted with currently available methodologies.

Moreover, the lessons learned from this earthquake should be utilized effectively in developing successful earthquake hazard reductional strategies to minimize the extent of avoidable damage in future earthquakes, at least in the seismically active regions.

Part 6 What the Major Earthquake Taught about Lifelines.

The Hanshin-Awaji Earthquake caused extensive damage to infrastructure lifelines, and had a significant influence on emergency systems immediately after occurrence of the earthquake and on both civic life and industrial activities after the earthquake. As the urban infrastructure becomes more and more complicated, urban activities depend more and more on lifeline systems. Lifeline earthquake engineering has evolved significantly in the past 20 years under these circumstances, and unique measures against earthquake disasters have been developed by suitably combining i) enhancement of anti-earthquake capabilities of individual facilities, ii) building of redundant networks, iii) protection by automatic control means in emergencies, and iv) recovery strategies after occurrence of disasters. The performance of such measures was tested by the Hyogo-ken Nanbu Earthquake.

The Lifeline Sub-committee, led by the respective suppliers and researchers from universities, has been studying lifeline facilities of supply/treatment systems (electricity, water supply and sewerage, and gas), communications systems (telephone and data communications), and traffic systems (railway and road) with the goals of thoroughly validating damages and of learning every possible lesson for the future. The subjects of subcommittee study can be roughly divided into the following three categories:

1. Behaviors of lifelines in the earthquake, and problems during recovery from the disaster;
2. Propagation of damage between the lifeline systems (cascade effect), and their correlations; and
3. Impact of functional failure of lifelines on the lives and social activities of consumers.

The first topic covers not only the actual state of damages, but also summarizes the measures against earthquakes that each provider has been taking (or will be taking) under the long-range view following its experience in the earthquake. Under the second topic, the disaster is analyzed from various aspects by researchers and engineers participating in the subcommittee. They summarize proposals for seismic diagnosis methods and study the impact resulting from propagation of disasters based on disaster data for water supply facilities, and also propose future measures against earthquakes for road facilities. Although correlations between lifelines have been pointed out for analysis even before the earthquake, there is a high possibility that specific data obtained from the Earthquake can be analyzed for future measures against earthquakes. In addition, further studies are expected to report on analysis of economic impacts from lifeline disasters and on suitable investments for measures against earthquakes. For the third topic, the subcommittee endeavored to clarify actual impacts on life by surveying members of the Kansai Branch of JSCE. The results should be particularly interesting because the impacts on the civic life from non-operation of lifelines are to be quantitatively summarized.

Part 7 Activities and Findings of Emergency Response Sub-committee

It was our basic mission to study and describe scientifically what happened in the impacted area for the first 100 days following the disastrous event of January 17 of 1995, which was the beginning of the Great Hanshin-Awaji Earthquake Disaster. This was the first major urban earthquake disaster since the Great Kanto Earthquake of 1923. The damages were so overwhelming in terms of its volume and its complexity that made us to critically review the earthquake disaster management system operated in Japan. Because of a severe lessons learned from the 1923 disaster, Japanese disaster management system has put strong emphasis on the promotion of structural mitigation measures. The 1995 disaster revealed that our mitigation level was not so high as we expected. It also revealed that our preparedness for crisis management in case of mass disaster proved to be insufficient and not well-trained. We now need to be more well prepared for large scale urban earthquake disasters which exceed our earthquake disaster mitigation level. We believed that a good preparation would be a result of good scientific description of what really happened at the time of disaster from the perspective of those who went though this disaster as either victims or disaster managers. Our team was started with a total of 26 members and ended with a total of 39 members. Our research team held 20 research meetings for three years, discussing many issues from the responses taken by Kobe Fire Department, Japanese Red Cross, and Self-Defense Force, the activities taken by the medical examiners association and various medical associations, to the responses taken by utilities such as NTT, Kansai Electric, and Osaka Gas. We also discussed various social impacts such as traffic congestion, voluntary involvement by outside helpers, business resumption, mental health care, and ethnography of how the local residents responded to the disaster. In addition, we study the policies taken and policy making processes by Hyogo prefectural government in such field as housing, employment, small business, and social welfare. The following was our two most important lessons from this tragic disaster in terms of post-disaster crisis management.

(1) Post-disaster crisis management consists of three independent tasks from the first day of disaster:

New and undesirable reality has been created in the impacted area due to this disaster. Reality itself has been changing rapidly. At the same time the full recovery of the impacted area will take more than ten years according to the restoration plans revealed by Hyogo prefecture and Kobe city six months after the earthquake. Thus, it is important to notice that social behavior reacting to the disaster would be different depending on the time frame upon which the observation was made as to what happened to the impacted community and the people in that area. Therefore, we would like to introduce the idea that post-disaster crisis management consists of the following three different tasks whose goals are independent with each other, and which would become apparent at different time phases during the disaster management processes. These three tasks are interconnected with each other at both individual-family level and community level. 1. Relief: Restoring social flow system (which may be symbolized by lifeline system) impaired by the disaster, and mass care during that period. 2. Response: Protection of human lives, provision of safety for the community, and prevention of secondary disasters. 3. Reconstruction: Reconstruction of both community as well as people in order to adapt to new reality created by the disaster.

(2) Disaster management is a decision-making process:

At the performance, these three tasks of post-disaster management, it looks apparent that there are different time phase in the order of response, relief, then reconstruction. As the operation, all of these tasks should be started right after the occurrence of disasters with three different teams working independently. Every once a while, it may result in conflicts among three working groups as to the priority of the operations. It would be the commander of the post-disaster crisis management operation to decide which operations should be prioritized taking into account the logistics both in terms of intelligence they acquired as well as the resources they could mobilize.

Part 8 Reconstruction and Restoration Process of Cities

The Hyogo-ken Nanbu Earthquake showed us various features of damages and socio-economic phenomena which was never experienced in the past as a near-field earthquake. The sub-committee for reconstruction and restoration process of cities focused on the following topics:

(1) transportation and traffic
(2) restoration process of houses and buildings and citizens' life
(3) information and communication

(4) socio-economic systems activities

In the topic (1), the functional damage features of transportation facilities and their restoration process were surveyed, and planning and countermeasures for strengthening the transportation systems were discussed. These include the following detailed researches:

(a) damage of roads and traffics immediately after the earthquake,

(b) private car usage and traffic accidents after the earthquake

(c) traffic control and regulation after the earthquake

(d) inter-urban transport of rescue and relief commodities after the earthquake and the rerated issues

(e) public transport and its alternatives

(f) role of marine transportation

(g) role of air transportation

In the topic (2), focusing on the restoration process of citizens' life, housing and transportation were surveyed and the related issues were discussed. These include the following researches;

(a) damage statistics of houses and buildings in Kobe

(b) blocked roads and inter-urban traffic

(c) refugee shelter and temporary housings and the related issues

(d) life of aged people and handicapped people after earthquake

In the topic (3), emergency communication and information for citizens were surveyed and the related issues were discussed. These include the following researches;

(a) telephone usage after the earthquake and related issues

(b) information supplied by newspapers, televisions and the Internet systems and related issues

In the topic (4), damage of industries and their restoration process were surveyed. These include the following researches;

(a) economic damage of industry

(b) restoration of industry and land-use change

(c) restoration process of citizens' life in relation to restoration of retail industries

(d) relation of supply facilities and citizens' life and issues of lifeline development

The Sub-committee intended to survey and analyze all of the socio-economic phenomena that happened to occur after earthquake. However, there were inevitably a limit to survey all the features because members of the group constituted of civil engineers whose major is infrastructure planning were limited. Therefore, the research results are not necessarily a satisfied one. But the results include various data and might give many suggestion for future urban system planning and management. They include the suggestion for urban disaster prevention planning, emergency response planning and restoration plan of facilities and citizen life.

The subcommittee strongly hopes that these results should be utilized for the future development of urban facilities and their planning.

土木学会関西支部
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写真-3.2.1 北淡町平林に現れた野島地震断層(朝日新聞社、1995年1月18日午後4時頃撮影) 北方を望む

写真-3.2.2 北淡町小倉に現れた野島地震断層(産経新聞社、1995年1月19日早朝撮影)　南方を望む

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写真-3.2.6 野島地震断層保存館内の北側トレンチ法面(1998年2月7日岡田撮影)

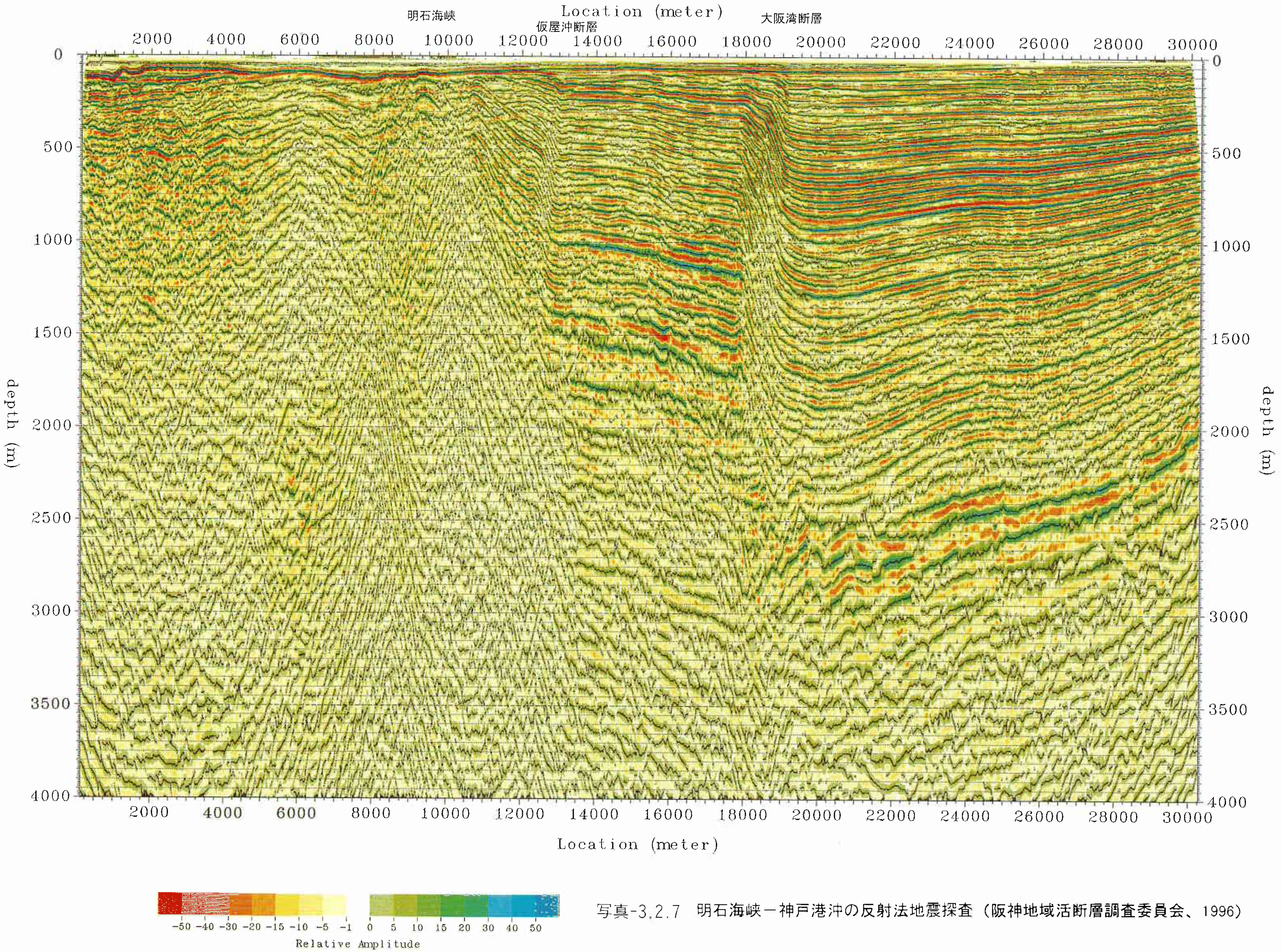

写真-3.2.7　明石海峡－神戸港沖の反射法地震探査（阪神地域活断層調査委員会、1996）

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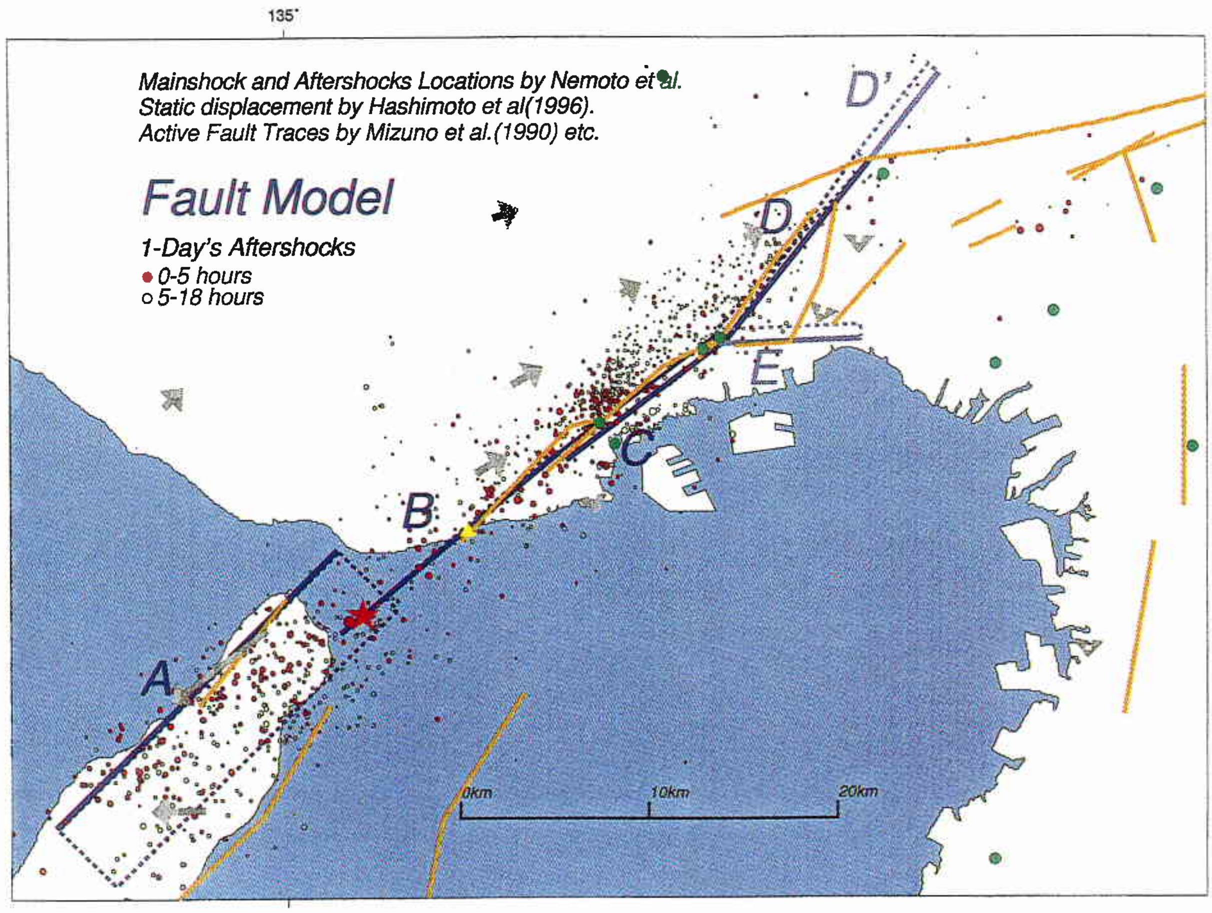

図-6.2.6 波形インバージョンのためにモデル化された震源断層面。余震分布、測地データおよび強震動記録による地面の揺れの軌跡を満足するように決められた。断層は４つのセグメント(A, B, C, D)からなる。

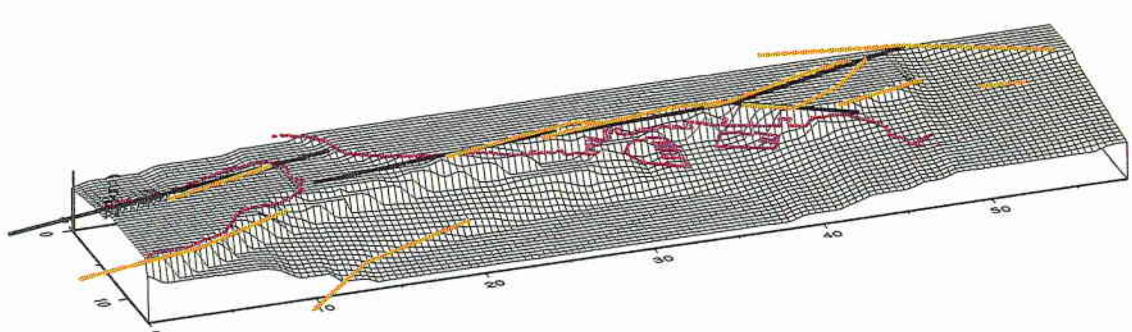

図-6.5.1 震源断層周辺域の３次元構造モデル。反射波探査断面を参考にモデル化。

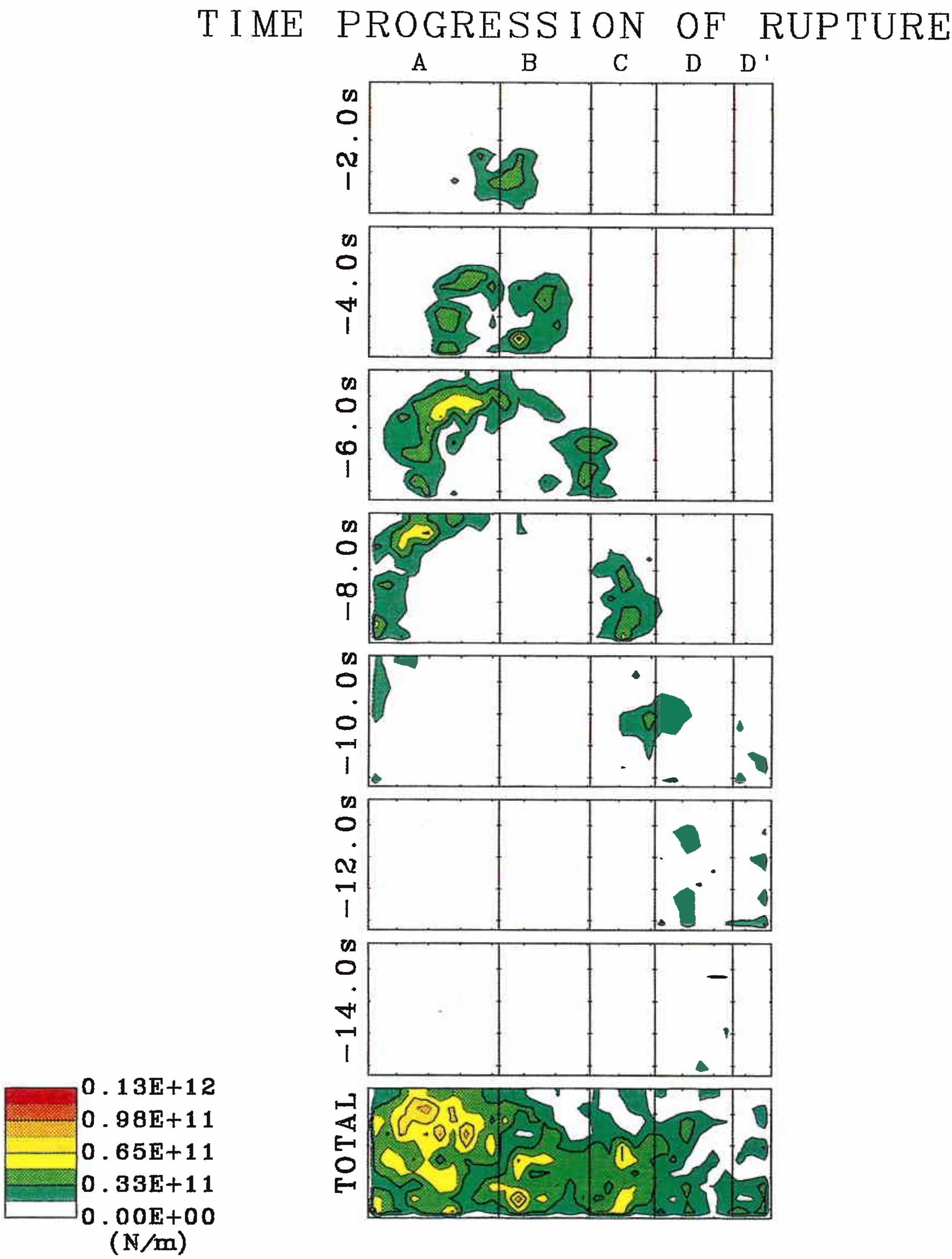

図-6.2.7 波形インバージョンにより求められた断層面内での地震モーメント解放量の時空間分布。

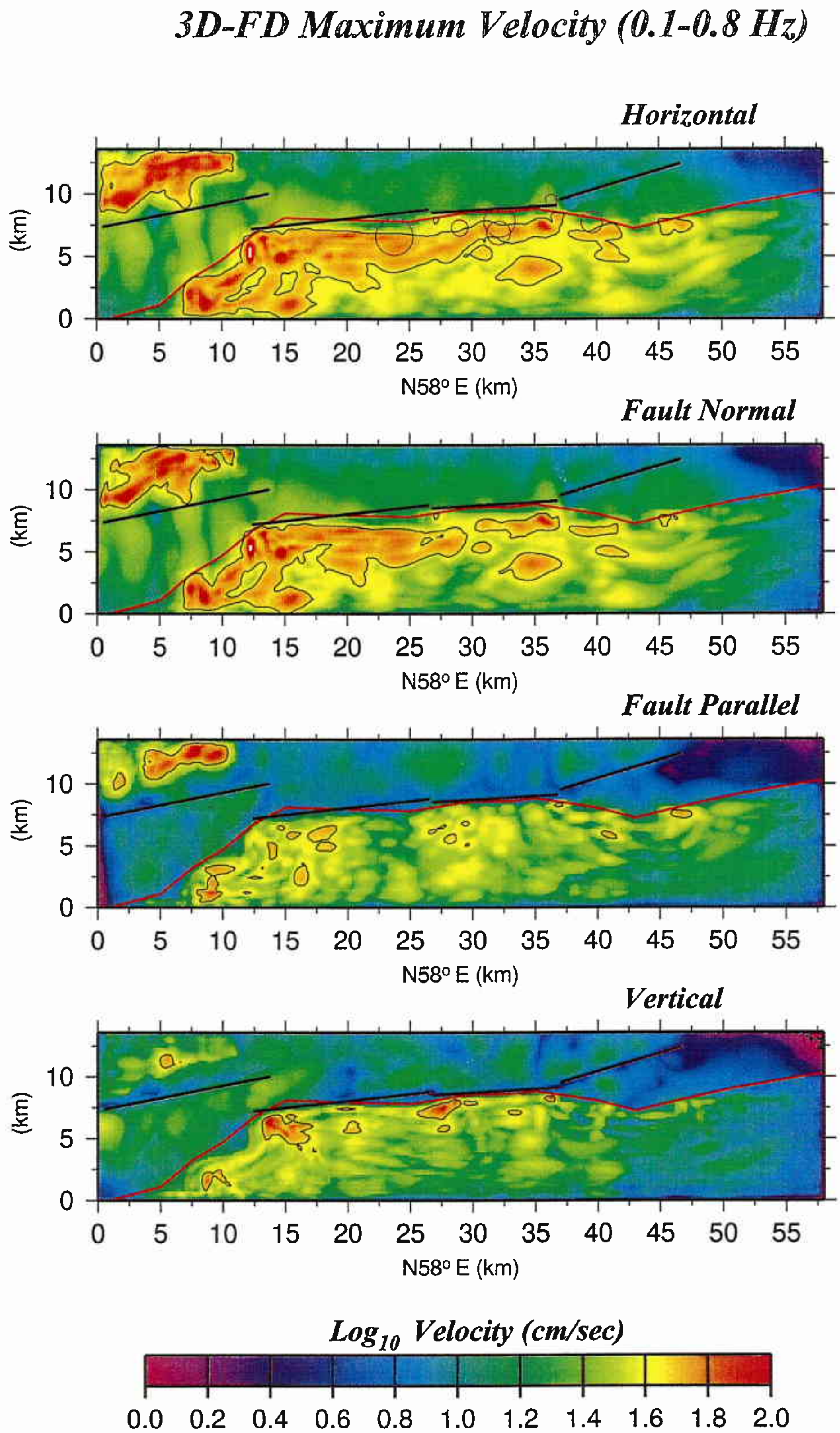

図-6.5.2 3次元構造モデル（図-6.4.8）とインバージョンによる震源過程（図-6.2.7）を想定したとき震源断層の周辺の地震動の最大速度の分布。
上から断層直交水平動、断層平行水平動、水平最大動、そして上下動。

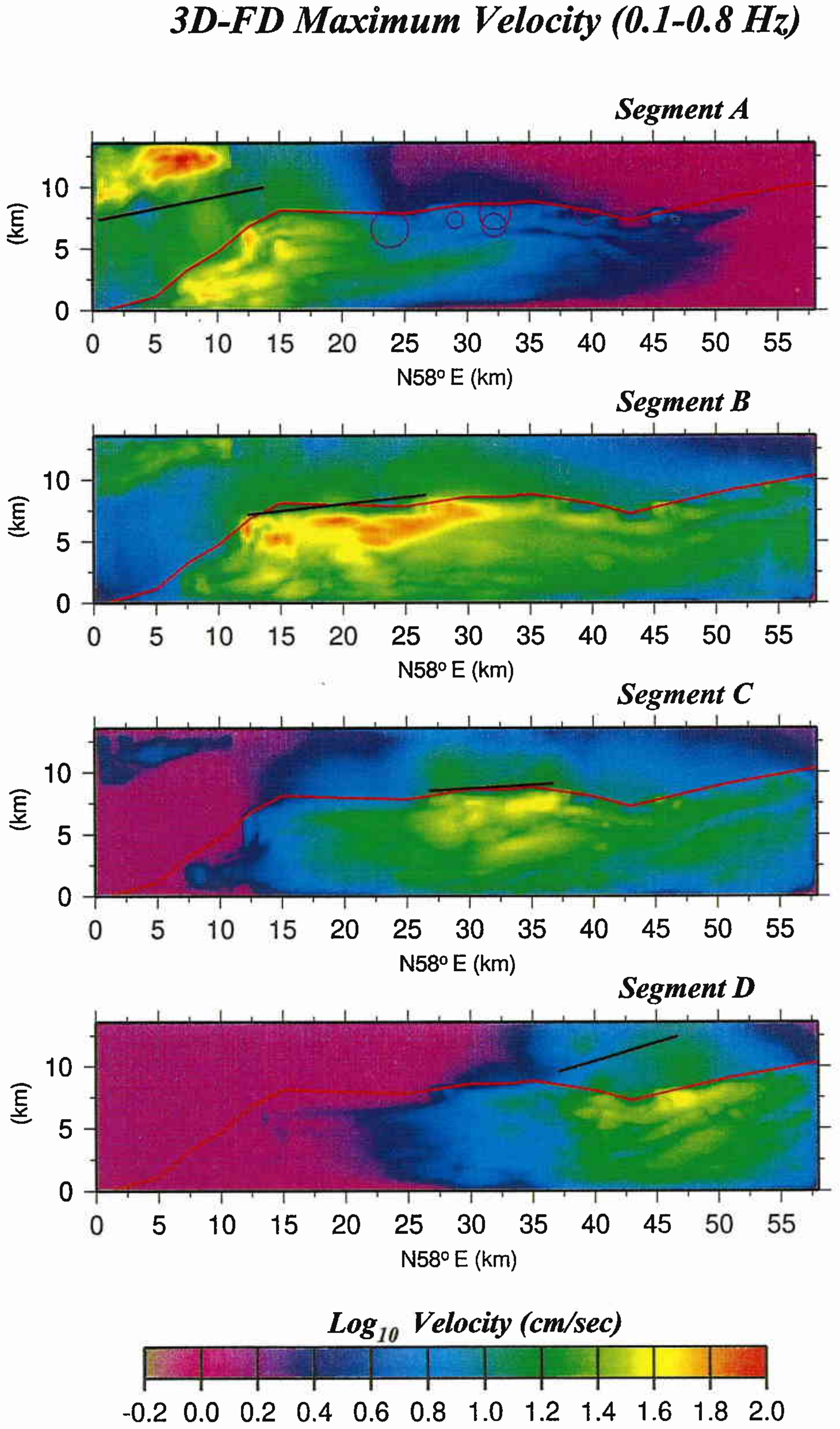

図-6.5.5 各断層セグメント(A, B, C, D)毎に生成される地震動(速度)の大きさの空間分布。

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