Department of Energy
Washington, DC 20585

JUL 19 1991

Mr. John J. Linehan, Acting Director
Repository Licensing and Quality
Assurance Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Linehan:

On May 14, 1991, the U.S. Nuclear Regulatory Commission (NRC) transmitted its Phase I review of the U.S. Department of Energy (DOE) Study Plan 8.3.1.2.1.2, "Characterization of the Yucca Mountain Surface-Water Runoff and Streamflow," and requested that DOE provide three hard-to-obtain references that are cited in the study plan.

Enclosed are the three references, published in foreign media, as cited in the subject study plan. A set has been informally transmitted to the NRC representative in Las Vegas, Nevada.

Should you have any questions, please contact Sharon Skuchko of my office at (202) 586-4590.

Sincerely,

Dwight E. Shelor
Associate Director for
Systems and Compliance
Office of Civilian Radioactive
Waste Management

3 Enclosures:

1. Beaty, C. B., 1974, Debris Flow, Alluvial Fans, and a Revitalized Catastrophism: Zeitschrift fur Geomorphologie Supplement, v. 21, p. 38-51.

2. Bergstrom, F. W., and Schumm, S. A., 1981, Episodic Behavior in Badlands, in Davies, T. R. H., and Pearce, A. J. (eds.), Symposium, Erosion and Sediment Transport in Pacific Rim Steeplands: Christchurch, January 1981, International Association of Hydrological Sciences Pub. No. 132, p. 478-492.

3. International Geographical Union, 1967, Field Methods for the Study of Slope and Fluvia Processes: Revue de Geomorphologie Dynamique, v. 17, No. 4, p. 146-188.

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Contributions. The Editor welcomes original papers, scientific notes, letters, and news items of worldwide interest. Please send material submitted for publication to: *Mrs Penny Kirby, Assistant Editor, IAHS, Institute of Hydrology, Wallingford, Oxon OX10 8BB, UK.* Original papers will be screened by two referees, usually chosen from the Board of Associate Editors. 'Instructions to authors' are available from Mrs Kirby.

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For over 50 years the proceedings of many of the symposia organized by the Association have been published. The address for orders for any of these publications is: *Office of the Treasurer, IAHS, 2000 Florida Avenue NW, Washington, DC 20009, USA.*

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All payments should be in 'hard' currency or internationally convertible monies, such as a US dollar bank draft.

Front cover MAIMAI EXPERIMENTAL CATCHMENTS, WEST COAST, SOUTH ISLAND, NEW ZEALAND. *Forest Research Institute (NZ Forest Service) photograph.*

Back cover TARNDALE SLIP, MANGATU, EAST CAPE, NORTH ISLAND, NEW ZEALAND. *Photograph by J. H. Johns, NZ Forest Service.*

David Meyer

EROSION AND SEDIMENT TRANSPORT IN PACIFIC RIM STEEPLANDS

SYMPOSIUM

EROSION ET TRANSPORT DE SEDIMENTS DANS LES TERRAINS RAIDES AU BORD DE L'OCEAN PACIFIQUE

IAHS-AISH Publication No. 132

Edited by Timothy R.H. Davies
Department of Agricultural Engineering
Lincoln College

and Andrew J. Pearce
Forest Research Institute
New Zealand Forest Service

Proceedings of the Christchurch Symposium, January 1981, sponsored jointly by The Royal Society of New Zealand, New Zealand Hydrological Society, IAHS, and the National Water and Soil Conservation Authority of New Zealand.

Actes du Colloque de Christchurch, Janvier 1981, parrainé conjointement par la Société Royale de Nouvelle Zélande, Société Hydrologique de Nouvelle Zélande, AISH, et l'Autorité Nationale de Nouvelle Zélande pour la Conservation de l'Eau et du Sol.

episodic erosion, where it is preserved, are numerous unpaired and discontinuous terraces, and experimental investigations of alluvial fan development revealed that aggradation is interrupted by episodes of fan trenching (Schumm, 1977). Therefore, episodic deposition as well as episodic erosion, should be recognised in steeplands. The two when occurring within a fluvial system can be referred to as the episodic behavior of that system.

Episodic behavior is not controlled by hydrologic events but by geomorphic threshold conditions. Depositional and erosional processes tend to build landforms toward critically unstable forms (thresholds) which will eventually fail causing a series of erosional and depositional events. When the adjustments are minor they are referred to as complex response. Such behavior may be intrinsic to the fluvial system (Schumm, 1977, 1979), and the threshold and complex-response concepts are integral parts of episodic landscape behavior.

In order to substantiate this model of fluvial system behavior, studies of long duration in steeplands are required, but what was, in effect, a model study of episodic behavior was made in a small badlands area in eastern Wyoming during the summer of 1978 (Bergstrom, 1980).

DESCRIPTION

The Kraft Badlands are located northeast of Lusk, Wyoming, and north of Pine Ridge, the southern boundary of the Cheyenne River Basin, at 42 58' north latitude and 104 9' west longitude.

The study area which is composed of four main drainages is 24.82 hectare. Seven tributary basins to these main streams were studied in detail.

The Kraft Badlands are typical of the area below Pine Ridge. Vegetation consists of approximately 10 percent groundcover of mixed grass and sagebrush with grass predominating. Soils are thin and residual with no profile development. When the vegetation and soils are breached, badlands form in the underlying readily erodible bedrock. The badlands display characteristics of steepland basins, steep straight slopes, wide braided channels and mass wasting.

The area is underlain by siltstones of the Brule formation of Tertiary age. Sediment is produced from bedrock by shrink-swell weathering. This process fractures the siltstone into coarse-sand and granule-size particles, that are then transported by winter winds and dry raveling to headwater channels and to lower-slope storage locations. Sediment is stored at these locations until summer thunderstorms deliver it to the main channel network. There is, therefore, a seasonal sediment-production-storage-erosion sequence, and the episodic behavior occurs annually in the badlands.

During the study all precipitation occurred as short-duration convective thunderstorms. Passing frontal systems were responsible for a series of these storms.

mass of sediment was delivered to the Zone 1-Zone 2 boundary. The stored sediment was removed from the Zone-1 channels and delivered downstream causing massive aggradation at cross section 7 (Fig. 3a) and somewhat less deposition at cross section 5 (Fig. 3b). The existing channels at these sections were filled, and a braided stream occupied the entire valley.

During period 3, the channel at cross section 7 degraded to the level of the high central terrace of the July 23 profile (Fig. 3a). The channel then incised to bedrock forming this terrace. The overall changes during periods 2 and 3 were characterised by abrupt filling and incision with a temporary pause (Fig. 3a). In contrast, in Zone 2, as exemplified by cross section 5, the channel filled during storm period 3, but it was incised episodically to form unpaired terraces (Fig. 3b). Therefore, the two zones were out of phase during the early part of the study.

In lower Zone 2 and all of Zone 3 there was general aggradation, but the amount varied from reach to reach and the valley floor was irregular with fans forming within the channel, providing the sites of maximum sediment storage.

EPISODIC BEHAVIOR

The observations in basin 1200 provide a basis for statements about the episodic behavior of the channels in the three zones.

Zone 1: An idealised sequence of cross sections in lower Zone 1 is shown on Fig. 4a. The numbers, 1 through 4, identify the altitude of the valley flow and channel at different times during the year. Winter sediment production covers the bedrock valley floor (1) and partly fills the valley (2a). Debris torrents during spring rains cause further aggradation (2b). Precipitation on bare slopes and upstream bedrock yields flashy sediment-free runoff, which causes incision and removal of much of the stored alluvium (3), and subsequent runoff events cause further incision back to the bedrock valley floor (4) leaving a valley-side terrace (3).

Zone 2: At stage 1 in Zone 2 (Fig. 4b) a valley fill is present (1). Early spring runoff incises the alluvium (2), and produces a terrace or multiple terraces. As sediment is introduced to Zone 2, as a result of major incision of the Zone 1 valley fill, aggradation raises the valley floor (3). When Zone 1 sediment production decreases, as the channels reach bedrock, the Zone-2 alluvial fill is eroded episodically (4a, 4b, 4c). Zone 2 is clearly out of phase with Zone 1. Zone 1 aggradation coincides with Zone 2 degradation and vice versa.

Zone 3: Only during the largest hydrologic events did runoff occur throughout the three zones. During small storms, when Zone 1 and/or Zone 2 were actively producing and transporting material, Zone 3 received little flow capable of modifying the valley fill (Fig. 4c (1)). Therefore, sediment was stored in Zone 3 (1, 2, 3a) and in-

Acknowledgements. The research reported herein was supported by the U.S. Army Research Office.

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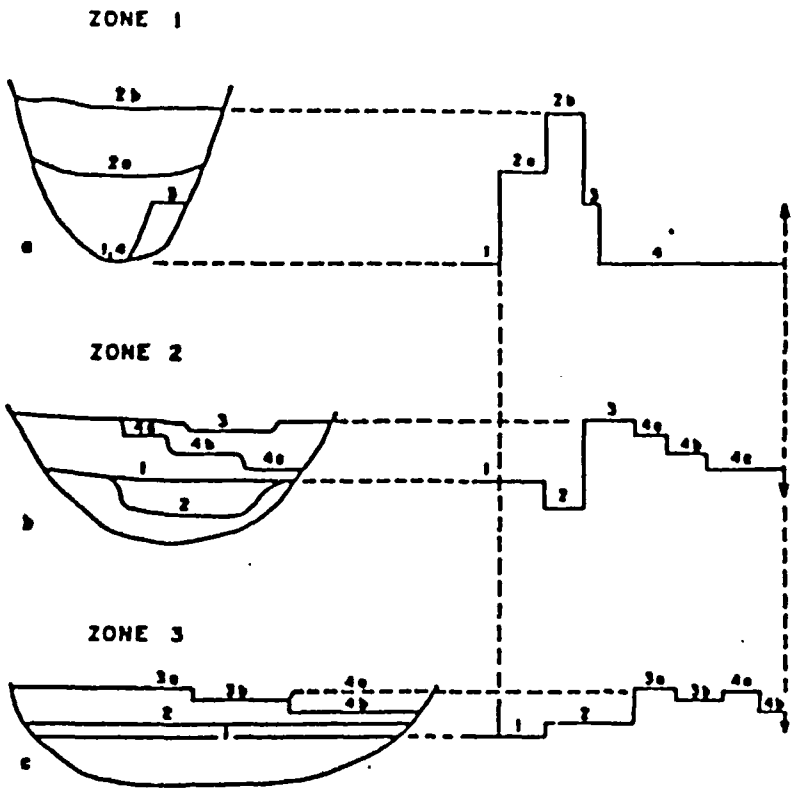

FIGURE 4. Idealised cross sections showing changes in Zones 1, 2, 3 during one season in the Kraft Badlands. Diagram to right of each cross section illustrates channel behaviour in each zone.

Erosion and Sediment Transport in Pacific Rim Steeplands. I.A.H.S. Publ. No. 132 (Christchurch, 1981)

Major sediment sources and limits to the effectiveness of erosion control techniques in the highly erosive watersheds of north coastal California

Harvey Kelsey, Mary Ann Madej, John Pitlick, Peter Stroud, Michael Coghlan, National Park Service, Redwood National Park, P O Box 55, Arcata, California 95521

Abstract. In the northern California Coast Ranges of the U.S., the combination of naturally unstable terrain and intensive landuse has created a need for erosion control programs to rehabilitate heavily disturbed slopes. In large drainage basins, 500-1000 km^2 in size, the major sediment sources generally occupy small, inaccessible portions of the basin that are in the stream channel or on footslopes adjacent to steep stream reaches. The best available erosion control measures, exemplified by those currently in use in Redwood National Park, are effective in dealing with erosion problems on heavily disturbed hillslopes. Early treatment of problems can prevent possible downslope cumulative impacts. However, because of the inaccessibility of the major sediment source areas, there is a limit to effectiveness of erosion control. Total drainage basin rehabilitation is not technically feasible, and basin-wide erosion control becomes, in part, a problem of managing land within recognised geologic constraints.

Sources principales des sédiments et limites à l'efficacité des techniques pour contrôler l'érosion dans les bassins hydrographiques extrêmement érosifs de la Côte Nord de Californie

Résumé. Dans les chaînes de la côte californienne du nord aux Etats-Unis la combinaison d'un terrain naturellement instable et d'une exploitation

Revue de GÉOMORPHOLOGIE DYNAMIQUE

Vol. 17, No 4, 1967

Sommaire :

Field methods for the study of slope and fluvial processes.

Techniques de terrain pour l'étude des versants et de la dynamique fluviale.

A contribution to the International Hydrological Decade.

Contribution à la Décennie Hydrologique Internationale.

No 4 XVIIe Année

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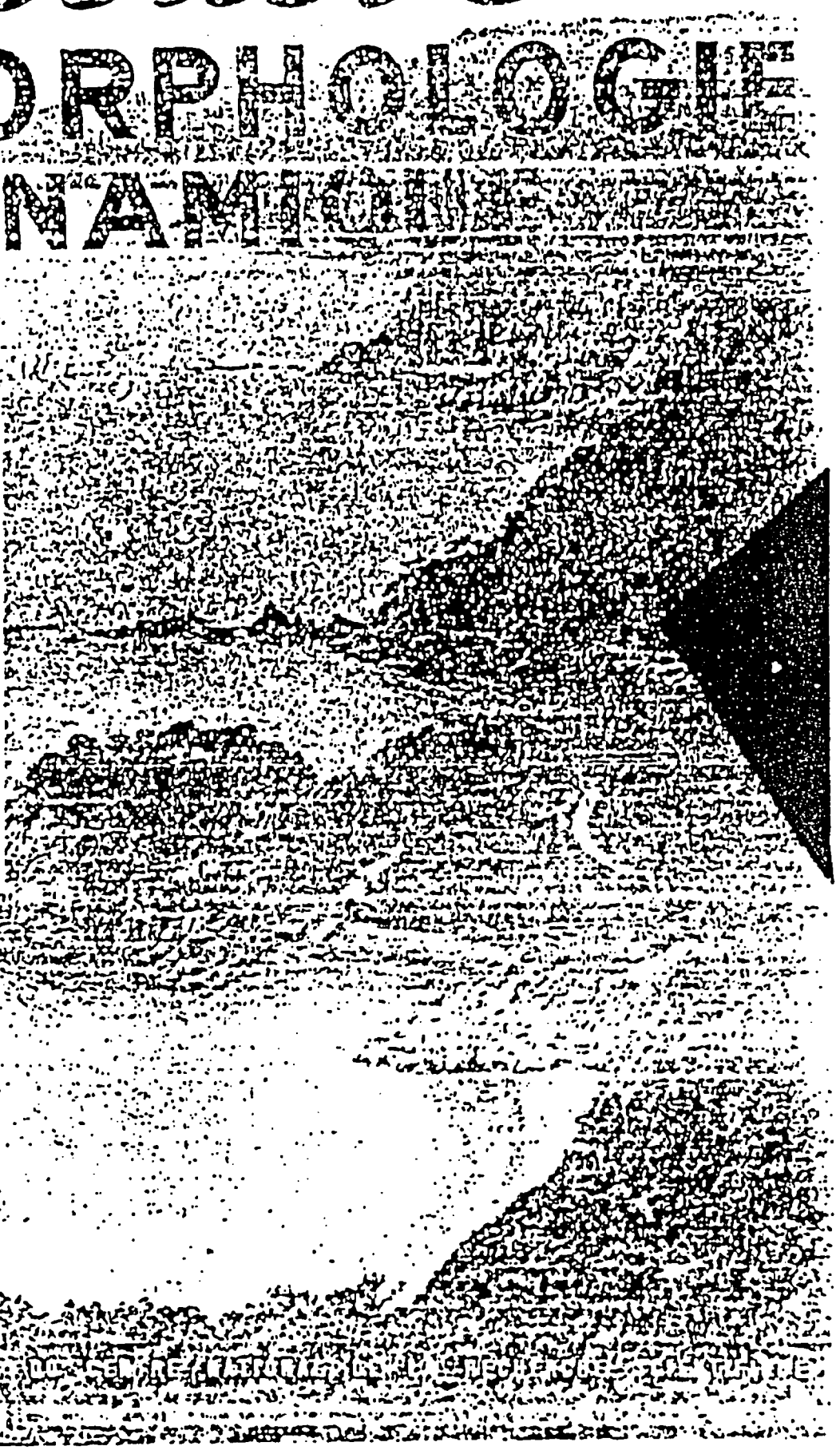

FIELD METHODS FOR THE STUDY OF SLOPE AND FLUVIAL PROCESSES

TECHNIQUES DE TERRAIN POUR L'ÉTUDE DES VERSANTS ET DE LA DYNAMIQUE FLUVIALE

A contribution to the

International Hydrological Decade

Contribution à la

Décennie Hydrologique Internationale

PREPARED BY THE COMMISSION ON SLOPES AND THE SUBCOMMISSION ON FLUVIAL DYNAMICS OF THE COMMISSION ON APPLIED GEOMORPHOLOGY INTERNATIONAL GEOGRAPHICAL UNION

OCTOBER 1967
OCTOBRE 1967

COMMISSION DES VERSANTS ET SOUS-COMMISSION DE DYNAMIQUE FLUVIALE DE LA COMMISSION DE GÉOMORPHOLOGIE APPLIQUÉE DE L'U. G. I.

NUMÉRO SPÉCIAL

pour le Congrès de New-Dehli 1968

AVANT-PROPOS

La Commission de Géomorphologie Appliquée a tenu, en Belgique, en juin 1966, une réunion commune avec la Commission des Versants. A cette occasion, sa Sous-Commission de Dynamique Fluviale, présidée par le Dr. L. B. LEOPOLD, de l'U.S. Geological Survey, a préparé une collection de courtes notes ayant pour objet d'exposer des méthodes simples d'étude sur le terrain des processus morphogénétiques.

Nous la présentons dans ce numéro de la Revue de Géomorphologie Dynamique.

Il s'agit d'une première tentative, encore bien imparfaite. Certaines notes présentent moins d'intérêt que d'autres, mais nous nous sommes interdit de faire un choix, contrairement à l'attitude habituelle que nous avons adopté à la Direction de cette Revue. En effet, lors d'une tentative préliminaire, il est bon que toutes les orientations soient représentées et que toutes les opinions puissent êt[re] connues. La sélection des meilleures ne p[eut] s'opérer qu'ensuite.

Conformément à l'un des principes [qui] toujours guidé la Rédaction de la R.G.D., n[ous] avons voulu, comme dans notre rubriq[ue] « Techniques de travail », mettre à la disposi[tion] tion du Public des méthodes directement applicables. C'est pourquoi nous avons insisté auprès des Auteurs pour qu'ils fassent part de tous les détails pratiques, qui conditionnent le succès de l'application d'une méthode, mais qui, malheureusement, sont trop fréquemment négligés dans les publications.

Nous souhaitons recevoir de nos Lecteurs des commentaires critiques sur ces méthodes et d'autres contributions du même genre. Nous les publierons bien volontiers.

J. TRICART.

Foreword

In Belgium during the summer of 1966 the Commission on Slopes and the Commission on Applied Geomorphology of the International Geographical Union sponsored a joint symposium, with field excursions, and meetings of the two commissions. As a result of the conference and associated discussions, the participants expressed the view that it would be a contribution to scientific work relating to the subject area if the Commission on Applied Geomorphology could prepare a small manual describing the methods of field investigation being used by research scientists throughout the world in the study of various aspects of slope development and fluvial processes. The Commission then assumed this responsibility and asked as many persons as were known to be working on this subject to contribute whatever they wished in the way of descriptions of methods being employed.

The purpose of the present manual is to show the variety of study methods now in use, to describe from the experience gained the limitations and advantages of different techniques, and to give pertinent detail which might be useful to other investigators. Some details that would be useful to know are not included in scientific publications, but in a manual on methods the details of how best to use a method has a place. Various persons have learned certain things which cannot be done, as well as some methods that are successful. It is our hope that comparison of methods tried will give the reader suggestions as to how a particular method might best be applied to his own circumstance.

The manual does not purport to include methods used by all workers. In particular, it does not interfere with a more systematic treatment of the subject (1) or with various papers already published in the present journal. In fact we are sure that there are pertinent research methods that we do not know of and the Commission would be glad to receive additions and other ideas from those who find they have something to contribute.

Also, the manual describes the methods in brief form. If further details are desired we urge that individual scientists correspond with their colleagues whose contributions are included in this little volume.

The Commission thanks all contributors to this manual and hopes that their contributions have been included in a satisfactory way. The Commission also thanks Dr. Luna B. Leopold of the United States Geological Survey, who at our request assumed the task of collecting the contributions, editing them and compiling the present work.

J. TRICART,
President Commission on Applied Geomorphology.

P. MACAR,
President Commission on Slopes.

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(1) TRICART (J.), 1965 : *Principes et méthodes de la géomorphologie*. Paris, Masson, 496 p., 36 fig., 8 pl. phot., 1 carte h.-t. coul.

CAILLEUX (A.) et TRICART (J.), 1963 : *Initiation à l'étude des sables et galets*, S.E.D.E.S., Paris, 3 vol., 2e édit.

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Nous souhaitons recevoir de nos Lecteurs des commentaires critiques sur ces méthodes et d'autres contributions du même genre. Nous les publierons bien volontiers.

J. TRICART.

best be applied to his own circumstance.

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Mesures au niveau Abney, praticables par un observateur seulement. Mise au net sous la forme de profils au 1/1 000e.

R. SAVIGEAR : Sur le levé des profils de versants.
Considérations générales sur l'intérêt des levés de profils de versants. Nécessité de décomposer la pente en segments à partir des discontinuités. Nécessité d'ajuster la précision du levé de terrain à l'échelle de la carte qu'on en tirera : rien ne sert de mesurer des unités trop petites pour être figurées.

O. FRANZLE : Sur l'utilisation de profils pour observer les horizons des sols.
Implantation de fosses le long de profils, complétées par des sondages en étoile permettant d'étudier un cercle de 200 m de rayon. Analyse classique des échantillons. Corrélation graphique de la granulométrie des horizons et de la profondeur.

H. VERSTAPPEN : Utilisation des photographies stéréoscopiques pour le calcul des valeurs de pentes.
La méthode Zorn donne des résultats précis jusqu'à 25-30°. La méthode Nekel aboutit à des erreurs inférieures à 2° pour les 2/3 des mesures quand les pentes sont inférieures à 40°. On peut les appliquer, en recourant aux lois de Horton, pour la mesure des pentes des talwegs.

L. B. LEOPOLD : Des archives des caractéristiques des pentes.
Définition des normes permettant de caractériser une pente. Il serait souhaitable que ce catalogue s'enrichisse d'observations normalisées portant sur des pays divers.

W. EMMETT et L. B. LEOPOLD : Observation des mouvements du sol dans des fosses.
Excavation d'une fosse pour placer des mires coupées en petits segments. Après rebouchage, au bout d'un certain temps, on excave de nouveau pour observer les déplacements. La méthode est améliorée en utilisant des plaquettes d'aluminium de 5 cm de large et 35 cm de long, verticales, fixées par un ruban adhésif lors de la mise en place et libérées ensuite par la destruction de ce ruban par la pourriture. Mesures au théodolite lors de la réexcavation.

R. HADLEY : Utilisation de trous remplis de sable coloré.
Utilisation d'un carotteur en acier de 12,5 mm de diamètre environ, 0,9 m de long et d'une baguette de 1,2 m en acier. On introduit les billes ou les particules de la même taille que le matériel naturel au moyen du carotteur qui est ensuite retiré. On observe les déplacements en creusant des trous.

J. RYBAR : Mesure des mouvements par observation des déformations d'un trou.
Implantation de tubes en matière plastique dans un glissement. L'observation de leurs déformations est continue. Des segments superposés de 0,5 de long sont reliés par un fil métallique qui sert à mesurer les déformations (aucune précision sur la méthode, J. T.).

S. SCHUMM : Déplacement de repères superficiels.
De divers types de matériaux, ce sont les cailloux de 50 mm de diamètre et 5-10 mm d'épaisseur qui constituent les meilleurs repères. Marquage par une tache de peinture d'aluminium. Il faut cependant faire attention à l'influence possible des oscillations thermiques. Nécessité de faire très attention aux modifications de la pente provoquées par le passage de l'observateur lui-même (et des autres personnes si la parcelle n'est pas rigoureusement interdite ! J. T.).

P. SCHICK : Marquage à la peinture de tous les blocs sur une petite surface-échantillon.
Dans le lit d'un oued, toute une surface nettement délimitée est soumise à une vaporisation de peinture. Prise de photographies-repères avant et après une crue pour déduire les départs de matériaux. Repérage des particules peintes déplacées en aval. L'avantage est de ne pas déranger le matériel (mais la rugosité et la cohésion des sables sont modifiées, J. T.).

L. B. LEOPOLD, W. EMMETT, R. MYRICK : Di[illegible] manières de peindre des blocs.
Utilisation de peinture à base de ci[illegible] résistante que celle à base d'huile. Choix [illegible] dont la dimension est un peu inférieur[illegible] dimension maxima moyenne. Les blocs sont [illegible] à des distances constantes les uns des autr[illegible] long du talweg, de l'amont vers l'aval. Chaque l[illegible] transversale de pierres peintes porte un num[illegible] correspondant à la distance depuis l'origine.

S. RUDBERG : Utilisation de pierres peintes disposées le long de courbes de niveau.
De préférence, on peint des pierres en place, disposées suivant des lignes droites correspondant à des courbes de niveau. La peinture se fait au moyen d'un fil à plomb et d'une ficelle tendue entre deux piquets. Le plus difficile est de trouver des repères parfaitement immobiles pour mesurer les déplacements. De la peinture à l'huile a résisté jusqu'à 10 ans dans les toundras suédoises. Les billes, par contre, sont détruites par météorisation.

S. SCHUMM : Piquets pour la mesure de l'érosion.
La longueur des piquets, leur diamètre et leur rigidité doivent être adaptés aux conditions locales (profondeur de la reptation, résistance du substratum). La mesure de la longueur de la partie aérienne du piquet n'a pas grande signification, aussi doit-on la remplacer par celle de la position d'une plaque coulissant dans le piquet, qui donne la surface moyenne du terrain sur une certaine aire. (Les travaux de G. ROUGERIE semblent ignorés. L'usage de la plaque ne semble guère convaincant, à cause des irrégularités du sol, aussi accidentelles à quelques centimètres du piquet qu'à son contact même, J. T.)

A. RAPP : Mesure des mouvements de solifluxion.
Combinaison de pierres peintes, de jalons en bois enfoncés de 40-50 cm et de mires enfoncées de 15-20 cm, le tout disposé en lignes. Pour les pierres,

on trace des lignes le long de fils tendus à partir de points fixes avec contrôle de l'alignement au théodolite.

J. PELISEK : Mouvements du sol sur les pentes montagnardes dus aux activités humaines, et leur mesure.

Etude des mouvements de terre provoqués par l'exploitation forestière. Utilisation de mires de 2 m enterrées à demi.

S.RUDBERG : Utilisation d'empilements-repères.

On creuse un trou au moyen d'une tige et on y place un tube d'acier dans lequel on fait descendre des cylindres de 2 cm de diamètre et de 2 cm de long, empilés les uns sur les autres et peints de couleurs vives. Les déviations de la verticale du tube d'acier sont préalablement mesurées au moyen d'un fil à plomb. On repère les mouvements, en général après 3 ans, par excavation.

S. SCHUMM : La végétation comme indice.

Observation du recourbement de la base des troncs.

S. RUDBERG : La végétation comme indice.

Base des troncs recourbée et enfouie dans un éboulis. Utilisation de la dendrochronologie pour calculer les vitesses.

R. CURRY : Utilisation de la végétation pour dater les unités géomorphologiques.

Utilisation des anneaux annuels de croissance des arbres et buissons pour dater des phénomènes ayant dénudé le sol ou des accumulations, et des lichens. Certaines espèces exigent une cinquantaine d'années pour coloniser la roche nue et meurent dans les trois ans sous un bloc retourné. Valeurs régionales de la vitesse de croissance.

J. PASEK et B. KOSTAK : Sur le déplacement individuel des blocs.

Blocs de roches dures sur matériel meuble ou friable. Mouvements très faibles. Utilisation d'un extensomètre robuste, mécanique.

S. RUDBERG : Fossilisation d'une couche identifiée par un matériel postérieur.

Ile de Gotland, Suède. Fossilisation des galets de la plage par des éboulements de falaises. Mesures volumétriques successives.

P. SCHICK : Construction de fosses.

Fosses avec deux caniveaux, un dans le fond, interceptant l'écoulement hypodermique, un en surface, l'écoulement superficiel. (Méthode antérieurement décrite et utilisée par G. ROUGERIE et dérivée des parcelles expérimentales des stations agronomiques. J. T.)

L. B. LEOPOLD et W. EMMETT : Plans d'une fosse de Gerlach.

Détails techniques pour l'installation du caniveau et du tuyau pour recueillir l'eau de ruissellement.

F. AHNERT : Méthodes seismographiques.

Utilisation du micro-sismographe Terra-Scout R-150 N'est valable que si la compacité des couches superficielles s'accroît en profondeur. Ainsi, ne peut servir lorsque le sol superficiel est gelé. Rend des services pour repérer l'allure du substratum rocheux cohérent sous une formation meuble. Les résultats sont mauvais quand la formation meuble contient des blocs nombreux disposés au hasard. La nappe phréatique renvoie les ondes.

R. CURRY : Photographie et stéréophotographie.

Système de photographies-repères répétées avec un appareil photographique ordinaire légèrement adapté. Permet une précision de 1 cm à 10 m de distance pour une focale de 55 mm. Sert à repérer des déplacements d'objets naturels, des migrations de repères, des modifications de l'aspect de la surface.

R. CURRY : Photographies répétées.

On peut changer d'appareil photographique à condition que tous aient le même rapport entre la longueur focale et la diagonale du négatif. On peut ainsi reprendre d'anciennes photographies et faire des mesures de déplacements d'objets.

O. STEHLIK : Méthodes de mesure de décapage pelliculaire et d'érosion en ravineaux.

Utilisation d'un avion modèle réduit guidé par radio pour prendre des photos stéréoscopiques.

R. EVANS : Inclinomètres et barres en T.

Méthode pour fabriquer des barres en T à bon marché. La torsion subie par la barre permet de calculer le déplacement à l'aide d'un niveau Abney.

J. DEMEK : Déplacement de pierres.

Comparaison de déplacements dans des types divers milieux. Les déplacements sont mesurés au moyen de polygones bouclés suivant les méthodes topographiques.

S. RUDBERG : Orientation préférentielle des pierres.

Mesures à des profondeurs étagées afin de mettre en évidence l'orientation dans le sens de la pente de la couche superficielle solifluée, différente de l'orientation initiale morainique sous-jacente. La couche superficielle atteint généralement 0,5 m de profondeur.

J. CUMMING : Limnigraphe à maximum.

Mode de construction, peu onéreuse, de cet appareil. La différence de niveau pour laquelle les mesures sont valables est d'environ 1,5 m.

P. SCHICK : Préleveur de suspensions.

Modèle simplifié dérivé de celui en usage aux Etats-Unis. Différentes variantes adaptées au type de régime des cours d'eau. Prix de revient allant de 20 à 40 dollars.

P. SCHICK : Trappe à sédiments de fond.

P. SCHICK : Sables fluorescents.

Utilisation sur des oueds. Description des manipulations. La luminescence est repérable sans instruments spéciaux.

R. BRYAN : Simulation d'averses.

Instrument utilisable au laboratoire. Mode de construction. Traitement d'échantillons de sol au laboratoire pour déterminer leur désagrégation dans des conditions conventionnelles.

T. PIPPAN : Glissements et coulées boueuses.

Relevé des renseignements fournis par les archives techniques des services de travaux publics et des chemins de fer, cartographie des données. Mesure des volumes mis en marche.

J. PASEK et J. RYBAR : Relevés technico-géologiques de glissements de terrain en Tchécoslovaquie.

Observations normalisées avec cartographie et mise sur cartes. Observation suivie des phénomènes avec relevés périodiques, mise en place de repères, etc...

T. PIPPAN : Mouvements de versants et soulèvement récent.

T. PIPPAN : Influence climatique sur les mouvements de masse.

Etude des conditions climatiques ayant précédé les mouvements de masse au moyen des archives. Corrélations graphiques.

MEASUREMENT OF SLOPES

Slopes Profiles

Field Surveys

On the field survey of hillslopes

Contribution by Anders RAPP, Uppsala (Sweden)

The following requirements are expected of the method.

1) An accuracy of about ± ½° of measured slope gradient.
2) The possibility of measuring a hillslope or valley-side of 50 to 300 m in height, and up to 35° gradient, in not more than 3-4 hours.
3) The measuring should not require more than two men's work in the field.

Equipment :

Inclinometer, type « Meridian » (Swiss made), a simple pendulum type. Scale in 360° degrees, from —43° to + 43°. Steel tape, 25 m or 50 m long, graded in cm. Field note book. Compass for reading bearing of the profile line.

Procedure :

The profile is generally measured upslope along a straight line following the maximum inclination of the slope. A benchmark or cairn is made at the beginning and at the end of the profile line. The two surveyors make stepwise readings, one measured length after the other, with a fixed interval in between them (generally 5 m or 10 m). Or the intervals can be flexible, adjusted to existing breaks in the slope.

The second man is reading the slope angle of each measured length with the Meridian pendulum. The first man is functioning as « eye-mark » in the readings. He also checks the distance of the measured length with the tape and takes the notes in three columns in his notebook. For each measured length he notes : 1) The distance from the starting point. 2) The inclination. 3) Remarks on the slope surface.

Average inclination from the beginning to the end of the profile is also measured with the Meridian pendulum.

The profile line can be reconstructed on paper by means of a protractor and can be combined with an inclination diagram (see Rapp. A., 1959, Avalanche boulder tongues in Lappland : *Geograf. Annaler*, n° 1, pp. 34-48).

On the field survey of hillslopes

Contribution by P. de BETHUNE, Louvain (Belgium)

This method has been developed for measurements in the Condroz region. (P. de Béthune, *Le Relief du Condroz.* Tijdschr. Kon. Nederl. Aardr. Gen., vol. LXXIV, 1957, pp. 220-233).

In this region of folded structure linear ridges and elongated depressions exhibit a cylindrical type of forms, in which the shape to be defined is the cross profile of the ridges. The method has been extended to non-cylindrical forms and used in various countries (P. de Béthune et J. Mammerickx, Etudes clinométriques du laboratoire géomorphologique de l'Univ. de Louvain, *Zeitschrift f. Geomorph.*, Suppiband, 1960, S 93-102). It has been systematically used in the last years to furnish a backbone to areal geomorphological mapping.

Equipment :

Abney hand level reading to 10 min[illegible] or Meridian clinimeter, reading [illegible] degree. Ten meter linen tape, o[illegible] that length. Staff with target m[illegible] height of the eyes of the surveyo[illegible] is held by a helper (any schoolboy [illegible] instead of a staff the helper may hold [illegible] at the exact height, if no helper is a[illegible] the surveyor may sight at a piece o[illegible] dragged along the ground at the end o[illegible] decameter (and apply a correction on [illegible] measured angle, see figure) ; in this case [illegible] box of expendable Kleenex napkins may b[illegible] useful to mark the station points.

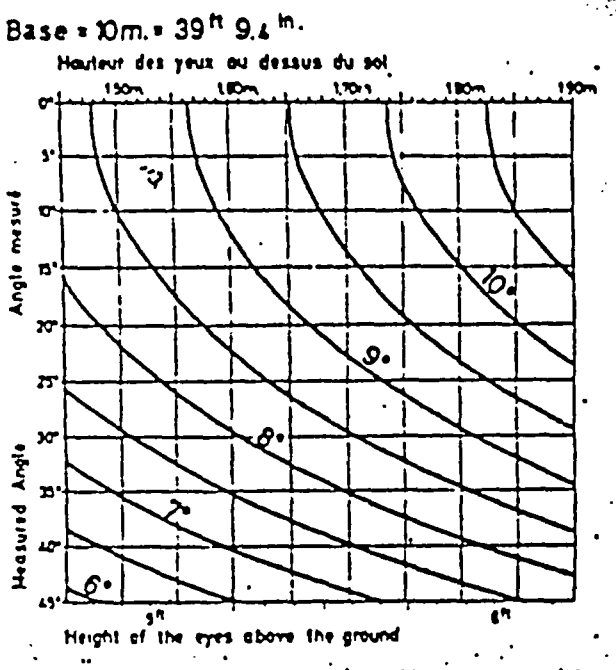
Procedure :

Choice of traverses. The chosen alignment must follow the line of greatest slope and pass between obstructions. Slight deviations around an obstacle may be allowed, or else the profile may be interrupted and a new one begun a few meters left (or right) at the same elevation.

The helper proceeds forward ten meters and holds the target at eye-level for the surveyor to sight at. He then marks the ground and proceeds another ten meters, measured by the decameter held between surveyor and him. When working without helper the surveyor sight backwards at the target pulled after him.

Length of steps — determined by the decameter at hand ; usually ten meter (29

9,4 in), but 50 feet (15,25 m) may be equally useful. Morphologically significant features are rarely so sharply defined that shorter steps should be taken ; if required the distance from the last station point should be measured and noted.



Diagrams :

Results of the profiling may be drawn at scale 1/1 000. One may check on the accuracy of is drawing by computing the differences of elevation, with a sine table and an adding machine. The results may also be drawn on a « slope-diagram » showing degree of slope against measured distances ; this allows one to recognize at sight the steepest slope, the significant breaks of slope either convex or concave, the stretches of constant slope, etc. This slope-diagram may be established at the scale at which the geomorphological map is being established, in order to carry its indications directly over on the drawing.

ON Surveying slope profiles

Contribution by R. A. G. SAVIGEAR, Sheffield (England)

Contours do not accurately portray slope morphology. Angular discontinuities, which are a very common feature of the ground surface, are generalised into zones of angular change and, unless the plane and curved surfaces of which it is composed are large in relation to the map scale and the contour interval, they give incorrect data regarding the occurrences and characteristics of these morphological units (1).

A line survey is probably the most accurate source of morphological data. If these are to be represented and analysed by the construction of slope profiles the scale barrier (which prevents the accurate representation of angular differences of less than half a degree and of very short measured lengths) makes it unnecessary to use more sophisticated instruments than the Abney level, the tape and ranging rods. Nevertheless the magnitude spectrum (which is a term used to describe the continuous gradation in morphological unit size from the textural units forming the surfaces of soil and waste fragments to those of continental magnitudes) makes it impossible to establish more than the most general rules for profile survey, since we dot not possess any exact criteria by which we can establish what forms within the spectrum should be identified in any particular site or situation. The field surveyor has to decide what forms are to be measured and we should recognise that the success of the profile technique depends on the appropriateness of the ad hoc decisions made by him in the field. Profile survey is therefore a technique of investigation as well as recording and the surveyor should be prepared to adapt his methods to record what he regards as the significant forms encountered.

Certain guiding suggestions may however be made. Experience suggests that a measured length of fixed span should be used for each component of the slope, say, 100 ft. for the footslope, 20 ft. for the backslope, etc., and this provides a check on the accuracy of the surveyor's identifications ; but it should never be applied without due consideration of the length of the profile, the spacing of the discontinuities, the characteristics of the units and the complexitiy of their associations. In addition other measurements must be made to locate the exact positions of discontinuities and other significant detail that would otherwise go unrecorded if a

(1) The terminology and techniques described are outlined and discussed in the following articles.

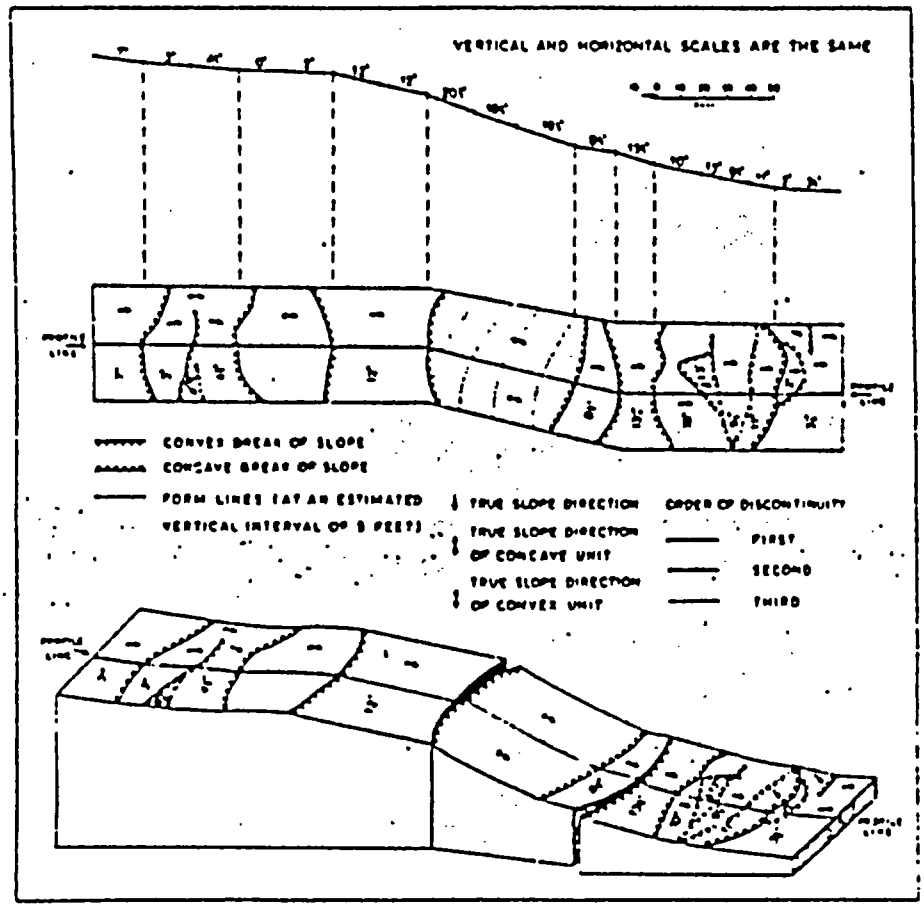
R. A. G. Savigear, A technique of morphological mapping: *Annals of the Association of American Geographers*, vol. 55, 1965, pp. 514-538.

R. A. G. Savigear, The analysis and classification of slope profile forms : Proceedings of the International Geographical Union Symposium on the Evolution of Slopes, *Geomorphic Cartography and and fluvial Dynamics*, Liège, 1966, In the press.

measured length of fixed span were to be used.

The major limitation of profile survey is that it provides information only for the survey line. When therefore a profile is reconstructed for analysis it stimulates more questions than answers. If, however, the morphology of the surface is mapped along the survey line (figure 1) at the same time as the profile is measured this assists the field surveyor in making his identifications, and it has the important additional advantage that it provides information regarding the areal extent and significance of the discontinuities at the stage of analysis and interpretation. The most accurate results are achieved if three or more parallel profiles are surveyed simultaneously and if the morphology of the ground between them is also mapped at the same time so that the exact positions of unit and micro-unit boundaries are located.

The morphological mapping technique recommented is based on the use of ornamented lines for the representation of the discontinuities (breaks of slope and inflexions) that separate the curved and plane units of the ground surface. The minimum sizes of the lines (1/50 in.), line ornamentation (1/16 in.), arrows and figures (1/8 in) and the scale of the base map define the minimum ground horizontal equivalents of the discontinuities, units and micro-units that can be represented. If contour or form lines are used to



Les échelles verticales et horizontales sont les mêmes.
Le trait sur le schéma en plan indique le tracé du profil.

Signes conventionnels, dans l'ordre :

— Rupture de pente convexe.
— Rupture de pente concave.
— Courbes épousant les formes (équidistance approximative de 1,5 m).
— Direction de la pente réelle.
— *Idem*, sur une unité concave.
— *Idem*, sur une unité convexe.

Ordre de discontinuité :
— Premier.
— Second.
— Troisième.

define the forms of the curved units a very precise statement of morphology can be obtained.

If a morphological map is presented without contours no information is available regarding relative or absolute height. The addition of a limited number of contours is therefore recommended. But the projection of morphological mapping symbols or contours onto the plane horizontal surface of the map gives inaccurate information regarding the shapes and areas of inclined units. These limitations may be partly overcome by the construction of strip maps of very narrow breadth on which correct inclined distances are represented. The construction of a block diagram based on one or more surveyed profiles (figure 1) is also recommended since it provides an accurate statement of the shape and area relationships of the units if constructed in the manner shown (figure 1). The relations of morphology to soil, rock waste and rock may also be represented on the face of the block.

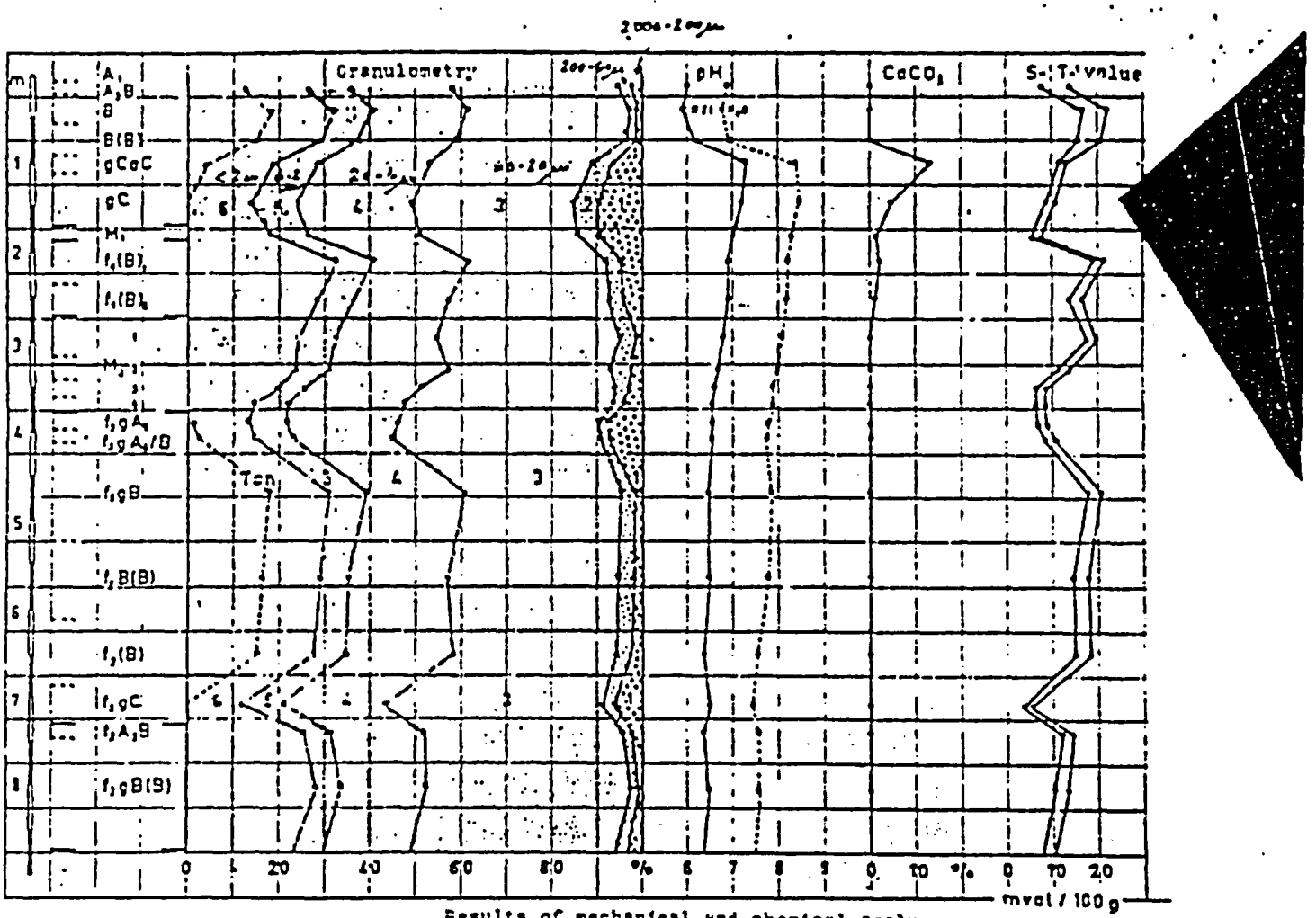
SOIL INVESTIGATIONS

On the use of cross sections showing soil horizons

Contribution by Otto FRANZLE, Bonn (Germany)

The separation of recent degradation and aggradation phenomena from older mass movements can be carried out by studies of soil profiles. Usually a series of borings are made or sometimes the soil profile is exposed in a road excavation or a large pit.

The soil profile examined in the pit or interpolated between the borings is used to describe the sequence downslope along a



Results of mechanical and chemical analyses

Résultats d'analyses mécaniques et chimiques
A gauche, granulométrie.

series of traverses emanating from a single central point in the small watershed and going in straight lines to the adjacent watershed divide. For example, from the central boring or pit three or four additional borings will be made to sample a distance of about 200 meters.

Not only is the soil profile described but also samples of various horizons are taken into the laboratory for analysis of grain size distribution and certain chemical characteristics. Samples from each depth are analyzed for grain size in 6 size-categories. The percentage of the soil sample represented in each category is plotted as a profile of size distribution with depth corresponding to these profiles values of pH, calcium carbonate, and cation exchange conditions (ST values).

These vertical profiles of the size distribution and of chemical factors both verify and help explain the horizons seen in the soil profile.

SLOPE VALUES FROM AERIAL PHOTOGRAPHS

On the use of stereophotos for computing slope gradients

Contribution by H. Th. VERSTAPPEN, Delft (Netherlands)

In the International Training Center for Aerial Survey at Delft there has been developed simple and satisfactory methods for obtaining values of steepness of slope by the use of overlapping aerial photographs (Stereoscopic). There has been published a detailed description of the methods and it is possible to obtain from the International Training Center transparent templates which are needed to apply the methods described. In the publication, which is referred to below, the material on the templates is published and could be copied onto transparent material for actual use. The use of the Zorn method will give results with very small error when the slopes are less than 25 or 30 degrees.

Another method is Nekel's « Slope Comparator », consisting of a small holder which carries a template and can be used under the stereoscope. This method will provide for 2/3 of the observations an error less than 2° provided that the slope gradients are less than about 40°.

Either the Zorn or the Nekel method can also be used to estimate gentle channel slopes from aerial photographs. This is an especially difficult problem when no ground control is available on the photographs. The method involves the relationship between the angle of bifurcation of the stream channel, the slope of the ground, and the slope of the channel — an equation presented by Horton (1945). Having measured the angle of bifurcation and determined the ground slope by the Zorn method, the slope of the channel can be computed.

REFERENCE

NEKEL J.F., SAVAGE J.F., and ZORN H.C., 1964. Slope measurements and estimates from aerial photographs : Publications of International Training Center for Aerial Survey, Delft, Netherlands, Series B, N° 26.

A LIBRARY OF SLOPE CHARACTERISTICS

A suggestion for compilation of comparable data on hillslopes in various countries and conditions

Contribution by Luna B. LEOPOLD, Washington (D.C.)

Most geomorphologists have seen in the field a great many kinds of hillslopes. Yet when we think back over what we have encountered in our experience, impressions are often more vague than we would like. It is for this reason that geomorphologists have turned to making measurements to supplement our visual impressions and our memories which are so fallible.

My colleagues and I therefore have started to collect a catalog, or what might be called a library, of slope characteristics. We plan to have comparable measurement data on a variety of slopes in different physiographic areas, of different relief, on different geology, and in different vegetation zones. How these data will be cataloged and indexed has not yet been determined, but it seems that the idea might have value for other geomorphologists also.

The following is a list of observations for each hillslope which will form a part of the library.

1. Longitudinal profile.

   With notes made in the field at equally spaced distances downslope ; on the occurrence of bedrock ; the percentage of surface area covered with rock fragments ; the percentage of area covered with soil material, and with vegetation.

2. Cross profile.

   Surveyed approximately parallel to a contour, with notes on bedrock, especially bedrock cropping out in the channels.

3. A description of the vegetation.
4. Drainage density on different slope segments.
5. Notes on dominant process.
6. Occurrence and nature of tors.
7. One or more photographs.
8. Data derived from the field survey and from maps.
   - Relief
   - Relief ratio
   - Horton analysis, including bifurcation ratio and length ratio
   - Concavity of the total slope and of slope segments
   - Regional data applied to survey area, including precipitation
   - Geology (rock type and age) ; soil type

As field data are accumulated in this catalog of slopes it will become more apparent what slopes tend to be concave, which convex, the relation of relief ratio to bedrock type, vegetation and climate, and other descriptive factors.

If scientists in various countries also accumulated field survey data on the occurrence of different kinds of hillslopes it may be profitable at some time in the future to combine these individual catalogs into a more comprehensive central repository of data on slope characteristics which could be consulted by any interested scientist.

SLOPES PROCESSES. RATES AND AMOUNTS

Pits, with emplaced rods or plates

On the observation of soil movement in excavated pits

Contribution by W.W. EMMETT
and L.B. LEOPOLD, Washington (D.C.)

For his work on mass movement in England, YOUNG described a pit into the side of which, in the undisturbed soil, were driven horizontal rods. The rods were arranged one above the other in a vertical plane and the plane went to a benchmark consisting of a steel rod driven into undisturbed soil at the base of the pit. With the passage of time the deviation of the emplaced rods from a vertical alignment gives some indication of the amount and rate of movement at various distances from the soil surface.

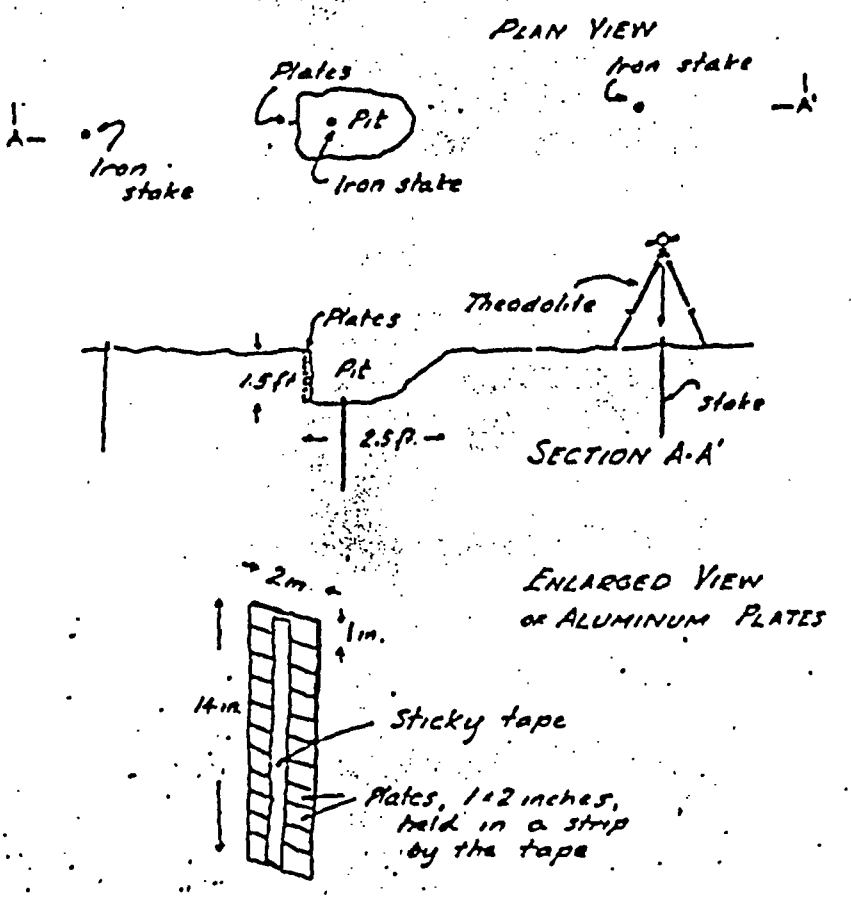
After the initial emplacement of the rods the pit is refilled and after an interval of time (six months or a year) the pit is re-excavated and, digging carefully up to the ends of the rods, their vertical alignment is re-surveyed.

In our experience with this procedure we used brass rods 1/8 inch in diameter and about 10 inches long. We had some reason to doubt that those small rods were indeed moving downslope with the moving soil. Some of our data indicated that either because the rods were too small or perhaps because they were too smooth, the soil was moving around them as if they were the roots of a tree. We therefore changed the procedure and substituted plates for the rods.

Digging a notch carefully into the undisturbed side of the pit an aluminum strip is inserted in a vertical position. The strip is about 14 inches long and 2 inches wide. Before placement the long strip had been cut into small rectangles 1 inch high and all the rectangles put back into their original alignment by the use of sticky transparent tape which holds them together during the time that the rods are inserted into the side of the pit. With time, the sticky tape is destroyed by weathering and the plates then can move downhill independently of each other.

The original survey and re-surveys are made with an engineer's transit or theodolite set up about 10 feet from the pit and about on the same contour, as shown in the accompanying diagram. The transit is set up over a benchmark consisting of an iron rod at least 3 ½ feet long driven vertically into the soil. The theodolite is oriented on a similar benchmark about 20 feet away on the opposite side of the pit. To make sure that the alignment of those two benchmarks is not disturbed by downslope motion, a third benchmark is driven vertically into the ground at the bottom of the pit and thus the top of that benchmark should be free of any downslope motion.

The survey consists of measuring, with the theodolite, the vertical and horizontal angles to the top corner each of the aluminum strips exposed in the side of the pit. The small distance between the theodolite and the strips to be measured is such that an engineer's theodolite which can be read directly to 30 seconds of arc means that downslope movements of less than about half a millimeter can be discerned with the survey method.



En haut, vue en plan du dispositif :
Plates = plaquettes. Iron stake = mire en fer. Pit = fosse.
Au milieu, profil selon la section AA'.
En bas, croquis montrant les plaquettes en aluminium, avec, au milieu, le ruban adhésif qui retient les plaquettes ensemble. Chacune mesure 2,5 × 5 cm.

COLORED SAND, MARBLES, RODS, AND HOLES

On the use of holes filled with colored grains

Contribution by R.F. HADLEY, Denver (Colo.)

Measurement of soil creep or mass movement on hillslopes has been accomplished using several techniques. The method described here is a simple, inexpensive way of determining downslope soil movement with minimum alteration of the physical environment.

The equipment necessary for this technique consists of four parts :

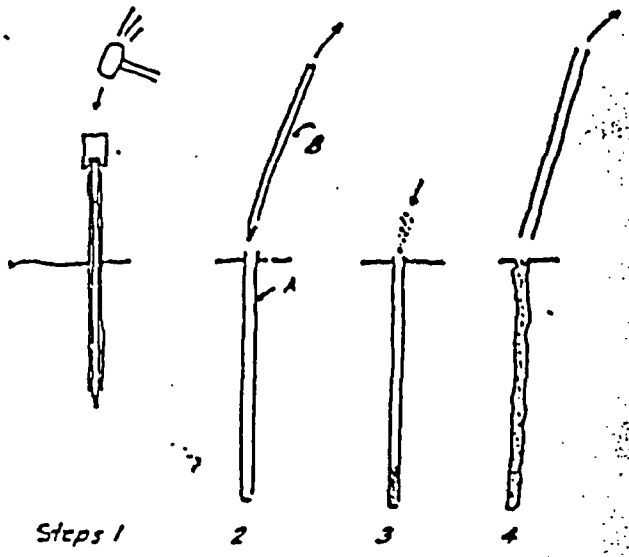
1) Hollow steel tubing about 3 feet long, 1/2-inch O.D., and 0.035 inch wall thickness. One end of the tube is slightly bevelled as a cutting edge (Part A in figure 1).

2) A solid steel rod about 4 feet long, 3/8-inch diameter pointed at one end for penetrating the soil. (Part B in figure 1).

3) A driving head made of steel that will fit over parts A and B, the tube and rod, for driving them into the soil.

4) Glass beads or colored sand grains having approximately the same median diameter as the soil on the hillslope.

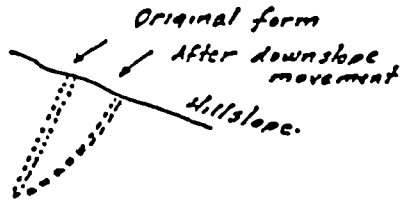
The solid steel rod (part B) is inserted into the hollow-stel tube (part A) and the two parts are driven into the ground to a depth of about 3 feet at an angle normal to the slope. The solid rod is then removed leaving the hollow tube in place. The hollow tube is then filled with glass beads or colored sand grains and the tubing is removed, leaving the column of beads in the soil. A series of holes both on contour and downslope in any grid pattern may be installed but care must be



1 : With rod inserted in tube and upper end filled with driving head, tube and rod are driven into ground.
2 : With draw rod.
3 : Fill tube with colored grains
4 : With draw tube.

1 : Avec la baguette insérée dans le tube et munie, en haut, de la tête pour le fonçage, fonçage en cours.
2 : Enlèvement de la baguette.
3 : Remplissage du tube par des grains colorés.
4 : Enlèvement du tube.

taken to survey the grid and establish permanent markers so that they can be relocated easily.



Le trait oblique represente la surface du sol.
A gauche, forme originelle.
A droite, déformation par le mouvement

The time interval between observations is governed by the objectives of the study : either cold season movement due to freeze and thaw or annual movement can be monitored. When the observation is made a hole must be carefully dug near the original installation so that a vertical profile showing the glass beads or sand grains can be exposed. If the soil is very dry at the time of excavation it is helpful to wet the ground so that the walls do not cave. The sketch of a hillslope above shows diagrammatically the type of movement that might be expected. The straight lines represent the original column of material and the curved lines represent the downslope movement, which in some cases resembles a vertical velocity profile in a stream.

The major disadvantage of this technique is that it is not repetitive in a single hole. Once the beads have been excavated it is not practical to use the observation site again. However, on a fairly uniform slope a series of holes on the contour will permit observations for several years on the same slope.

On movement measured by survey of a deforming hole

Contribution by Jan RYBAR, Prague

In the vicinity of the Nechranice dam site a detailed investigation of an experimental landslide on an area of 55 × 35 m is taking place. The area is built by pre-consolidated claystone of Miocene age of « fissured clay » character. The excess loading in the upper part of the slope started the slide in 1961. After detailed mapping/1:250/, longitudinal and transversal sections were measured and observations lines plotted across the slide. Individual points of these lines are measured once a month. At irregular intervals the movements are also checked photogrammetrically and mechanically, on the strainmeter principle, with the possibility to get a continuous record on a registering device. A system of tubes lowered into bore holes or test pits was used to ascertain the real position of the sliding plane. The 0,5 m long tubes are of plastic material. A wire fixed to each tube leads through all superposed tubes to the registering device on the surface. Movements under the active sliding plane are registered by the shifting of the corresponding wire.

Movements above the sliding plane can hardly be ascertained in this way. Therefore, an inclinometric measurement in a resistive, flexible tube, placed with one set of the above mentioned tubes, was carried out. In exposing cemented bore holes by tests pits approximate data on the changing velocity of the movements are obtained.

Climatic influences are investigated on the spot in a hydrometeorologie observatory. Hydrogeologic observations are supplemented by pore-water pressure measurements.

During a standstill period, the investigated slide was artificially revived by an excess loading in the upper part of the slope.

in large channels. A simpler technique may be employed. Starting at the mouth of the ephemeral rill, the drainage area of which may be several acres, individual rocks are picked out of the channel for painting. In a channel where the grain size varies from sand to 4-inch gravel the rocks chosen are of a relatively uniform size between 2 and 4 inches in diameter. Once the size has been chosen in an individual rill all rocks painted should be close to that same size.

The rocks are located at 10-foot intervals along the stream channel, beginning at the chosen downstream point. After being completely coated with paint the individual rocks are placed at uniform intervals up the thalweg of the rill.

When the initial coat of paint is dry the rocks are numbered with a new color, the numbering system beginning at the most downstream point and each number represents the distance in feet upstream from base point. Thus the rock placed 250 feet upstream from the base line will carry the number 25. At the time of resurvey the movements of individual rocks can be easily distinguished owing to the fact that the painted rocks will no longer be equally spaced, nor will they be in consecutive order.

REFERENCE

LEOPOLD, LUNA B., EMMETT, WILLIAM W., and MYRICK, ROBERT M. 1966. Channel and Hillslope Processes in a Semiarid Area, New Mexico : U.S. Geol. Survey Professional Paper 352-G, pp. 193-253.

On the use of painted rocks aligned along a contour

Contribution by Sten RUDBERG, Göteborg

Lines of painted rocks have been used by the author since 1955 to get the mass-movement rate on gentle and medium steep slopes in mountains in Sweden. In the investigated regions the loose deposits are mainly till within the tundra zone, but to a large amount locally derived weathered material in the higher frost-shatter zone. The surface layers in the latter type of areas are rich in stones and boulders and almost free of higher vegetation.

The mass movement lines of painted rocks have been arranged in straight lines, more or less parallel to the contours. The stones to be painted have been chosen normally in their original position, but in areas with few stones and boulders occasionally suitable specimens have been taken from areas outside the line and put in the desired position. The rocks of the line have been painted by using a plumb line and a string, stretched half a meter or less above the ground between poles of some kind (iron rod, steel tubes, etc., fixed in the ground). The weight, or plumb-bob, which is cone-shaped, is dipped in the oil-paint and lowered to the stones to be marked, giving a small patch of color, which afterwards is enlarged with brush, if necessary.

One problem is to find bench marks for reference. When possible they are sought for on outcrops, and a whole series of markings are painted in the true direction of the string, by using the plumb line. If no solid rocks are found within the area, large boulders are used in spite of the possibility that even these boulders are slightly moved. When later checking the line the same benchmarks and the same method with string and plumb line is used, but with new colors, one for each time of checking. The amount of movement is measured on the ground between two different colored markings, and in the direction of slope. The distance between each painted rock in a line varies, and ranks from one to several decimeters.

The actual experience shows that the till in the tundra zone moves more or less as a continuous mass, but that the difference between individual sections of the measured line is far more pronounced in the frost shatter zone, and the rate as a whole much lower. Thus more densely spaced markings and a higher grade of accuracy should be needed in the latter zone. The used oil paints (Swedish marks as System) have in some cases lasted 10 years or more, in others less. Occasionally marbles have been used instead of painted rocks, but without success, since they easily weather.

Lines of painted rocks are often combined with « test pillars » whic hare intended to show the vertical velocity profile.

STAKES, VEGETATION, and OTHER MARKERS

Erosion measured by Stakes

Contribution by S.A. SCHUMM

Installation. Stakes which are driven into hillslopes for the purpose of obtaining infor-

mation on the sion of the hillslope by progressive exposure of the stake must be placed on the hillslope in such a manner that they do not disturb the ground surface unnecessarily and that they are fixed in position. One needs, therefore, to use stakes of sufficient length so that they will not be affected by surficial creep or frost action.

The stakes should be long (2 ft to 3 ft depending on local conditions), thin (1/4 inch in diameter), smooth and strong. If long, they will not be influenced by surficial creep ; if thin, their effect on surficial runoff and erosion will be minimized ; if smooth, they may resist frost heaving ; if strong, they can be driven into weak bedrock.

The top of each stake should be exposed a few inches above the ground surface, in order that they can be more easily located for repeat measurements. If a portion of each stake is exposed, it is unlikely that they will be buried and lost.

A major problem is that of taking meaningful measurements that can be duplicated by other investigators. Measurement of stake exposure from the top of the stake to the ground surface at the base of the stake is not a good technique, because such a measurement could include any accelerated erosion at the stake base caused by the installation of and the presence of the stake on the hillslope. In addition, the value obtained will vary depending on irregularities of the ground surface. Therefore, one should measure from the top of the stake to the average ground surface. This can be achieved by the use of a plate several centimeters in diameter, which has a hole in its center somewhat larger than the diameter of the stake. This plate can be lowered to the ground surface with the stake projecting through it. A measurement from the top of the stake to the surface of the plate will yield the distance from top of stake to the average ground surface.

On the measurements of solifluction movements

Contribution by Anders RAPP, Uppsala (Sweden)

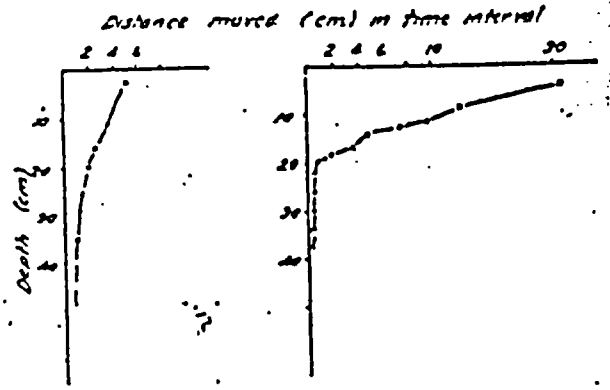
In Karkevagge (1), solifluction movements were recorded by annual checking of markings in dow...slope and transverse test lines. Three types of markings were used : (1) Oil paint on boulders and cobbles. (In many cases the stones more rapidly than the ground itself, probably due to stronger frost-heaving and needle ice action). (2) Wooden stakes driven vertically 40 to 50 cm into the ground. (3) Stakes driven 15 to 20 cm into the ground. To these markings for recording surficial movement, test pillars were later added for checking the vertical velocity profile in the ground.

The stakes form two downslope lines over the talus cone onto the solifluction slope below. The interval between two stakes in each line is about 20 to 40 m. Between the two downslope lines there are several transverse lines of painted markings on stones or small stakes in the ground.

Positions of the markings were checked with a steel tape once every summer. Measurements were started from a fixed point (FO) on the rockwall, 1.5 m above the talus top. By using two plumb bobs the accurate distance between the stakes in t... downslope line was measured 30 cm a... the ground. Measurements are estim... accurate to ± 0.5 cm per measur... Lines should be checked from ... in bedrock at the lower as well ... end of the line. This method is ... recommended chiefly for recordi... ments in talus slopes, where no fixed ... occur on the talus mantle.

A more accurate measuring method ... established in a test field arranged by ... author and L. TJERNSTRÖM in 1962 at th... Tarfala field station in the Kebnekaise mountains of northern Sweden. Straight and nearly horizontal lines are established by oil paint on the talus slopes and by oil paint, wooden pins, test pillars on the lower till-covered slopes. Wooden pins were driven about 15 cm into the ground. Each test pillar was about 0 .7to 0.9 m long, consisting of wooden cylinders, 1.2 cm in diameter and 2 cm in length. The lines are checked by theodolite readings from fixed points in bedrock combined with straightened, thin wire fastened to bedrock fixes at both endpoints. Wire straightening is checked in the theodolite. On every stone crossed by the fixed wire a line 1 to 2 cm wide is painted and located vertically from the wire by a plumb bob.

(1) See Rapp, 1961, p. 173. (from Rapp A., 1961 Recent development of mountain slopes in Karkevagge and surroundings, northern Scandinavia, Geograf.Annaler, 42 : 2-3, pp. 71-200).



Distances de déplacement (en cm) pendant le temps unitaire en abscisse.
Profondeur (en cm) en ordonnées.
Variations du mouvement du sol suivant la profondeur en utilisant des pilliers témoins.

of a test pillar is marked on the ground with a short wooden stake, and the distance and direction between the base of this stake is measured to benchmarks, painted on solid rock when necessary on large boulders.

If possible, different benchmarks are used in varying directions from the stake. If, after some years the stake has proved to move, the pillar is dug out by means of a shaft at the side of the pillar and with a vertical wall in the direction of supposed movement. In this wall the pillar is cautiously freed from soil to approximately half the diameter of the cylinders. Then a plumb line is placed in the original position of the stake and is used as a coordinate, to which the horizontal distance of each individual cylinder is constructed in a graph after necessary correction for the original dip of the pillar.

The test pillar method usually requires 3 years before excavation. In some cases only one year is necessary. All localities have so far been in till areas, and all but one above the timber line. The lower part of the pillars often prove not to have moved at all. Therefore this lower part helps to fix the original position of the pillar. Two examples of data in accompanying graph show different profiles of movement. These probably reflect different processes of movement, such as mainly differential frost-heaving at different depths or a sort of surface flow.

Practical problems with the method are the difficulties to inject the pillars by means of simple equipement and to get good marking of the position. The stakes often disappear.

On the use of welding rod for erosion and deposition pins

Contribution by R. EVANS, Sheffield, U.K.

It has been found that welding rod of 0.125 inch diameter, which does not rust, is a more satisfactory material to use for erosion and deposition pins than iron or steel nails. Because of its diameter disturbance of the soil is at a minimum as is resistance to soil movement and, since the rod is manufactured in 3 foot lengths, it may easily be sunk until a rock fragment or bedrock is reached and the appropriate length cut off. Penetration of the rod to a hard surface is very important where frost may occur since in these conditions the rod may be heaved out of the soil and give a false measurement of movement. If it can always be pressed back to its original depth the true amount of displacement due to heave, and the subsequent loss of waste on thaw, can be measured. The exposed ends of the rod are painted red for ease of location.

Modified Depth Gauge for Erosion Rod Measurement

Contribution by R. EVANS, Sheffield (England)

Where erosion rods are used the distance between the top of the rod and the washer or the soil may easily and accurately be measured by the use of a modified depth gauge (Rabone Chestermann Ltd., Sheffield). This is easy and quick to use and has a vernier scale which reads to 0.10 mm. (Figure at right). The projecting wings of the original gauge sawn off to make a more compact instrument.

Measuring hillslope erosion

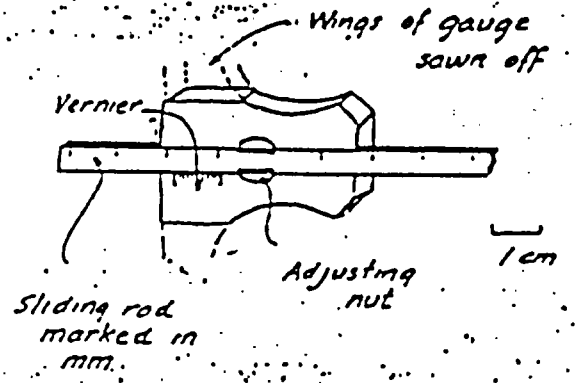
Contribution by N. J. KING and R. F. HADLEY, Denver (Colorado).

Measurement of aggradation or degradation on steep hillslopes presents problems of either physically altering the land surface during observations by trampling or artificially influencing natural processes if pins or other such devices are used. The erosimeter described here is designed to measure changes on steep hillslopes without physically disturbing the slope in any way during observations.

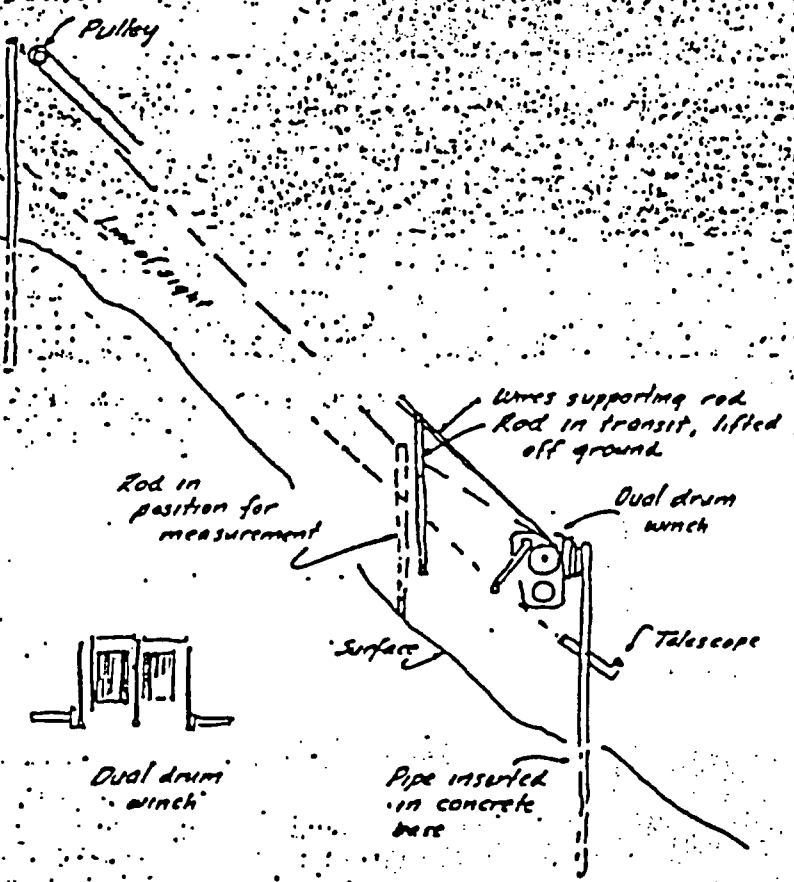
Fundamentally, the device is a modification of the pulleytype clothesline. Two elongated pipe sockets are mounted permanently in concrete, one at the top and one at the bottom of each hillslope section to be measured (see fig.). The top of each pipe socket

is set approximately flush with the ground level. Between observations, both pipe sockets are capped to exclude water and sediment. When measurements are made, the cap is removed and a pipe is inserted into each socket so as to form a rigid post extending vertically about 5 feet above ground level. A pulley is mounted on one post and a dual drum winch containing 1/8-inch nylon line is mounted on the other (see fig.). The line from one drum of the winch is passed over the pulley wheel and fastened to the line on the other drum forming a closed loop. A graduated plumb rod and the zero end of a surveying tape are fastened to the point of juncture of the two lines. By cranking one of the winch drums with the right hand and the other with the left, the looped line can be loosened or tightened so as to lower or raise the plumb rod. Once the rod is raised off the ground it can be moved upslope or downslope by cranking both drums in unison.

In operation, the rod is lifted off the ground by tightening the lines and then moved to the point of the next reading. The rod is then lowered until it just touches the ground. The slope distance can be read directly from the tape attached to the top of the rod. The height



MODIFIED DEPTH GAUGE



Mesure de l'érosion des pentes *(en bas)*

Un piquet permet d'accrocher un fil qui est tendu, au bas de la pente, grâce à un tambour double (schéma en bas à gauche), fixé sur un socle.

Les mires sont suspendues à ce fil et abaissées au contact du sol pour les mesures au moyen du télescope fixe sur le socle en béton.

Jalon modifié *(en haut)*

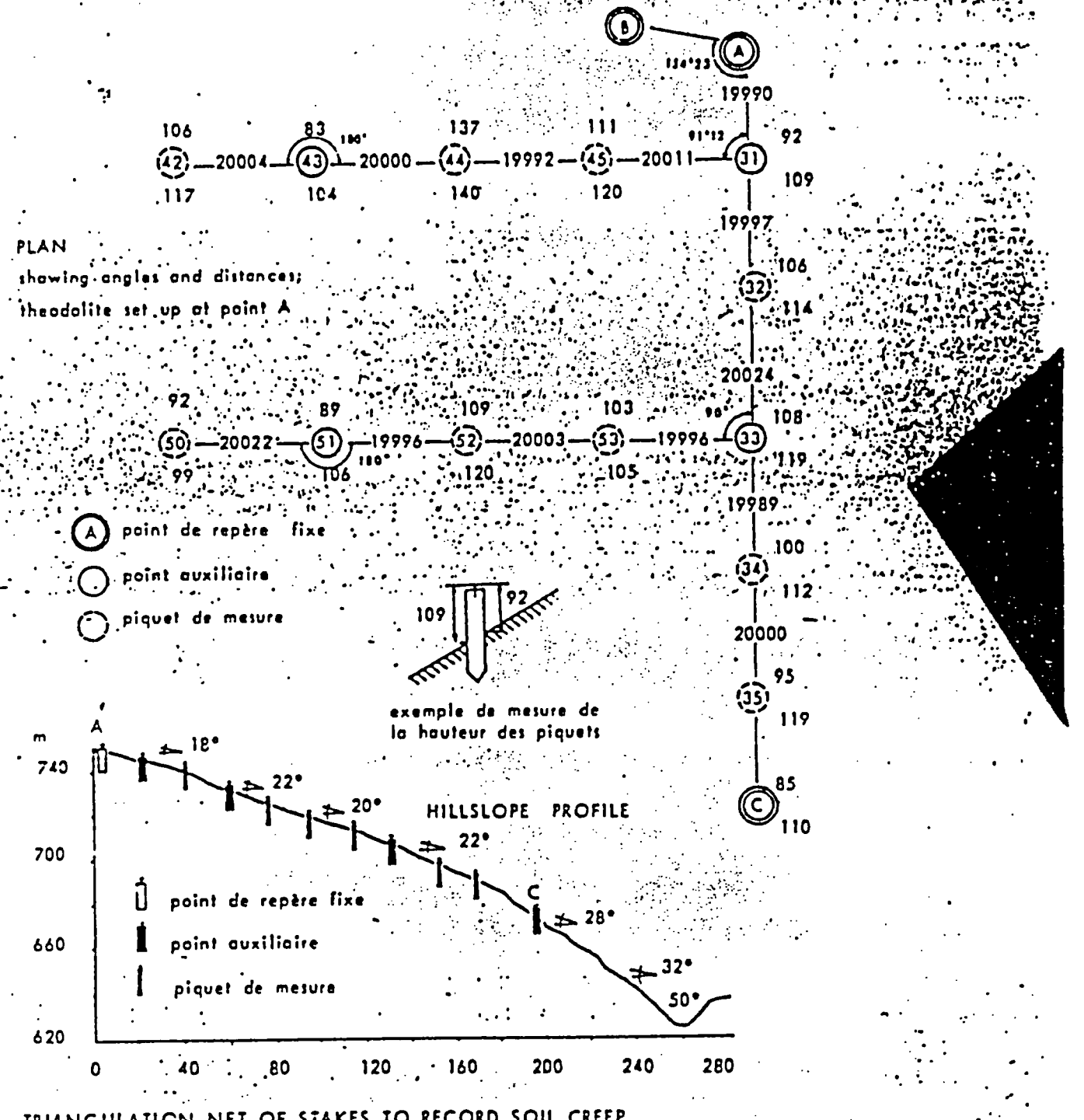
La réglette, graduée en millimètres, coulisse dans un vernier. Les ailettes de ce jalon ont été sciées.

of ord is read throught a telescope mounted on the post below he winch (see fig. 1) and adjusted to a predetermined line of sight.

On the placement of stakes for measuring downhill crepp

Contribution by T. GERLACH, Krakow.

For a network of stakes to measure downhill creep we used oakwood stakes having a dimension of 50 × 4 1/2 × 4 1/2 cm pointed at the end. They are driven into the ground at a depth of 40 cm. We find a rock located at the hill top and there set up a metal reference point A which cannot move. In the same vicinity, also on a permanent rock, we set up a



TRIANGULATION NET OF STAKES TO RECORD SOIL CREEP

second metal reference point B. When the theodolite is set up on A the sight on to B provides for orientation. It is necessary that all points on the hillslope which are to be measured can be seen from point A where the instrument is set up. In the direction of greatest inclining towards the talweg we set up a permanent reference point C. In the straight line from A to C stakes are driven into the ground at various distances. Some stakes on the line A-C are also end points for lines of stakes approximately parallel to the contour. What we call the auxiliary points are marked by long stakes, usually 120 cm, driven 110 cm into the ground. The regular measurement points are marked with 50 cm stakes driven to a depth of 30 to 40 cm.

The method, as in the case of other stake observations, requires re-surveys in subsequent years initial installation. The measurements depend primarily on the angle measured by theodolite from the instrument set up at A to each individual stake. The new position of stakes are computed by trigonometry. Distances between pairs of stakes on the main line A-C and on the additional lines of stakes parallel to the contour have been measured with a metal tape. For accurate measurements the tape is always stretched with a constant force of 10 kilograms. In addition we measure precisely the height of each stake above the ground surface ; also the angle of inclination from the vertical is recorded for each stake. The methods used allow us to observe a movement which is barely perceptible, that is, it only attains an amount of movement of several millimeters.

VEGETATION

On vegetation as a marker

Contribution by S.A. SCHUMM, Denver (Colo)

It is well known that on unstable hillslopes the roots of vegetation will show the effects of mass movement. The roots will anchor the plant, but downslope movement of the soil will, nevertheless, carry the plant downslope and the roots will appear to be bent upslope. A sharp bend in the roots of some plants may occur immediately beneath the ground surface. These features indicate in a qualitative way that mass movement is occurring on a slope, but they yield no information concerning the rates of creep or whether the movement is seasonal. However, the distortion of roots of annual plants do yield information of this sort. A plant that commences to grow in the springt of the year and yet shows measurable root distortion in the summer indicates that mass movement during the spring and early summer is important. In addition, the amount of root distortion may yield a crude measure of the rate of creep during part of the year.

On vegetation as a marker

Contribution by Sten RUDBERG, Göteborg (Sweden)

In one special site on Axel Heiberg Island, Canada N.W.T., buried willow-tree trunks were tentatively used for measurements of movement on a scree slope. The trunks were bent in a downslope direction from the roots, and parts were covered by stones belonging to the ordinary scree cover. The lengths of the buried trunks, measured in the downslope direction from the roots to the superficial parts of the willow, were - 220, 55, and 205 cm in the three examined specimens. Samples from the trunks were taken and the number of rings were calculated in microscope, which gave respectively 64, 40, and 67 years. The amount of movement in a year was respectively 3, 7, 1, 4, and 3,0 cm - which look to be quite reasonable figures.

In the birch forests of the lower mountain slopes in Sweden the trunks of the trees are usually bent. A simple measurement of the direction of the bends indicates, in a specially measured area, a clear maximum in a downslope direction.

On use of vegetation to date land surfaces

Contribution by R. CURRY, Berkeley, (Calif.)

In the Sierra Nevada of California, methods have been established to aid in determining the ages of both depositional and erosional portions of mountain slopes. The ages of trees, determined by counts of assumed annual rings, is not of great value for this purpose since most species can tolerate modest degradational root exposure or depositional burial without mortality. In alpine, subalpine, and montane vegetational regions, old photographs taken in the 1870's to 1890's have consistently suggested to this author that shrubs, grasses, and lichens are in many instances more longlived than most tree species and that methods should be sought to date these plants.

Shrubby genera such as *Salix*, *Cercocarpus*, and *Artemisia* have proved to add annual rings with at least the fidelity of most trees and are even less likely to have missing or double rings than some arboreal genera such as *Juniperus*. Although rings are too

close together to count without polishing the section and viewing it under a microscope, some relatively inconspicuous willows less than 1 m high have proved to be 500 years old. Shrubs up to 100 years old can usually be roughly dated directly in the field by counting annual rings with the aid of a pocket hand lens. Alpine cushion plants, as well as sedge and grass culms have shown little or no change over a period of 90 years but no means has yet been found to date the first appearances of these plants.

Lichens have proved the most useful for dating land surfaces. By measuring the maximum diameter of the largest lichen thallus found on a given physiographic feature (glacial trim-line, mudflow channel or debris, etc.), one can estimate the age of that lichen where the growth rate curve for that particular species growing on that particular substrate in that climate is known.

The lichens that have been found most useful are those crustose and squamulose species with very slow growth rates that are relatively unaffected by the different rock types upon which they grow. Most such species colonize a bare rock surface within 50 years and, if that surface is covered or the rock turned over, the lichens will die within three years. For the first 100 to 300 years of growth, the species used in my work grow at a much faster rate than they do for their total 2000 to 6000 year potential lifespans. Species used in the Sierra Nevada of California are as follows :

Species	*Overall growth rate for first 1000 to years of life*
Rhizocarpon superficiale *Rhizocarpon lecanorium* *Rhizocarpon geographicum group* *Acarospora chlorophana*	1.0-6.0 mm/century
Sporostatia testudinea	5.0-8.0 mm/century
Lecidea aetrobrunnea	about 20 mm/century

The values are valid only for the Sierra Nevada above 2400 m elevation and only for lichens growing on non-calcareous metamorphic rocks, granitic rocks, and basalts. Andesites and limestones affect the growth rates very greatly, as does the length of the snow-free season and availability of summer moisture.

Growth rate curves for given areas can be established by measuring the largest thalli of a given species growing upon dated materials and by taking into account the 30 to 50 year initial colonization period typical of many crustose species. Glacial moraines of known age and periodic alpine mudflow levees that bury turf which can be dated by C^{14} are excellent features for such use. No lichenometry should be attempted by the ecologically naïve.

On movement of individual blocks

Contribution by Jaroslav Pasek
and Blahoslav Kostak, Prague, Czechoslovakia

Among different slope movements a special position is that of block-type movements, where blocks of solid rocks resting on softer materials, creep very slowly downwards along the margins of slopes.

In Czechoslovakia, the geologic conditions favor in several cases the development of such deformations. Such phenomena are known in the first place from valleys in Cretaceous sediments, where claystones or marlstones are overlain by horizontally bedded solid sandstones. The marginal parts of sandstone tables are dissected by a system of fissures, single large sandstone blocks are shifted and tilted, and the wide fissures form in places bizarre labyrinths. Similarly, in Flysch regions large sandstone blocks glide downslope on the tilted clayey intercalations ; in open fissures, partially reclosed by smaller blocks, cave systems develop. Widespread movements of this type are known from younger volcanic mountains, where large basalt or andesite blocks move on the underlaying clays, claystones or tuffs. Blocks of volcanic rocks shifted for several hundred metres form conspicuous morphologic elevations.

These movements are supposed to be fossil, Pleistocene in age. As in most cases the same geological and geomorphological conditions still exist, it may be assumed that this process will continue. The movements being almost imperceptible (only mm within 10 years), they cannot be traced in the customary way. Here aerial photogrammetry is one of the possibilities. The comparison of aerial photographs in intervals of 10-20 years and the topographic evaluation of given points should reveal if a shifting has taken place.

For direct measurements of slight deformations a new type of extensometer was developed. It is fixed in a fissure and enables the verification of the relative and arbitrary movements of adjoining blocks. The extensometer works on a pure mechanical principle with an accuracy of ± 0,1 mm. Cantilevers

leading the movements of the comparative marks are fixed to the walls of the fissure. For these marks optical grids were used. The relative movement of the marks may be investigated on the basis of the mechanical interference of grids either by direct reading or from a photo of the characteristical interference fringe pattern. Each extensometer works with two pairs of these marks which enables to measure the components of the movement in two concurrent planes. In such a way the resulting vector of movement may be found. The device is relatively simple, and it can be assumed that it will be possible to follow the progress of the deformation for a long time.

Lacking experience, we must suppose that only an extensometer working on a simple mechanical principle is sure to work trustworthily. That is the reason why electrical extensometers have been avoided so far. On the other hand, the sensivity of the device need not be too gigh, as the influence of the thermal dilatation should anyway be excluded. Thus it is necessary to find for the vertification of block-type movement dilatations systematically exceeding thermal dilatations.

On the covering of an identifiable layer by new material

Contribution by Sten RUDBERG, Göteborg

The method described is tried at the island of Gotland, Sweden, and may be specially adapted to its conditions. The rock of the cliff is limestone and mainly marl, the latter being friable and easily weathered, mainly during late winter. The coast is open in the quadrangle SW-NW. There is no tide, but the non-periodic changes of sea level might be at least a half meter or maybe one meter.

The shore is covered by well rounded gravel, mainly consisting of the rock in place but to a small amount of Precambrian crystalline rock in some places. The cliff is 10-15 m high and its base is situated at about 3 m above sea level. This base is normally covered by talus, consisting of fragments from the wall and to a large part, lumps of clay derived from he weathering clay, these latter constituents brought in their present position partially by mud flows. The breakers normally do not erode the talus. During exceptional storms, however, and especially storms combined with a high water level, the breakers reach the talus, which is more or less removed and replaced by well rounded shore gravel. This shore gravel is then by degrees covered by new talus.

An estimation of the wall retreat is got by measuring the talus covering the gravel in a certain place (e.g. a surface 0,5 m or 1 m long parallel to the cliff). The age of the shore gravel can occasionally be stated (e.g. big storms 1931, 1948, 1954). It is also possible to make estimates on late winter snow, or to get an artificial reference surface by placing a piece of sacking on the talus. Still better is to make a volume measurement at a certain time and another one some years later in the same place, provided that no great storm has occurred during the years between. The different measurements have given figures of the same order of the wall retreat, which in most places is 2-5 mm in a year. The figures should according to the methods be regarded as minimum values. The traditional, comparative morphological analysis indicates a somewhat higher speed of the slope retreat.

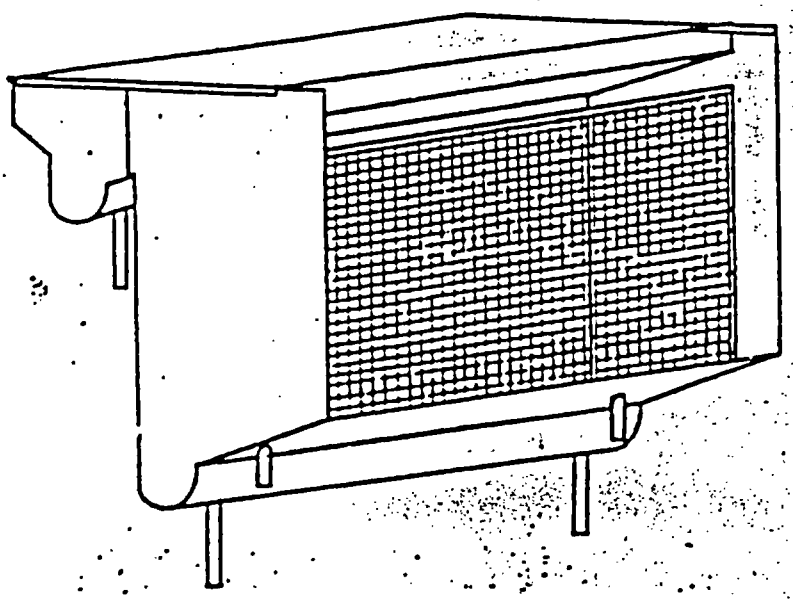
GERLACH TROUGHS-OVERLAND FLOW TRAPS

On the construction of troughs

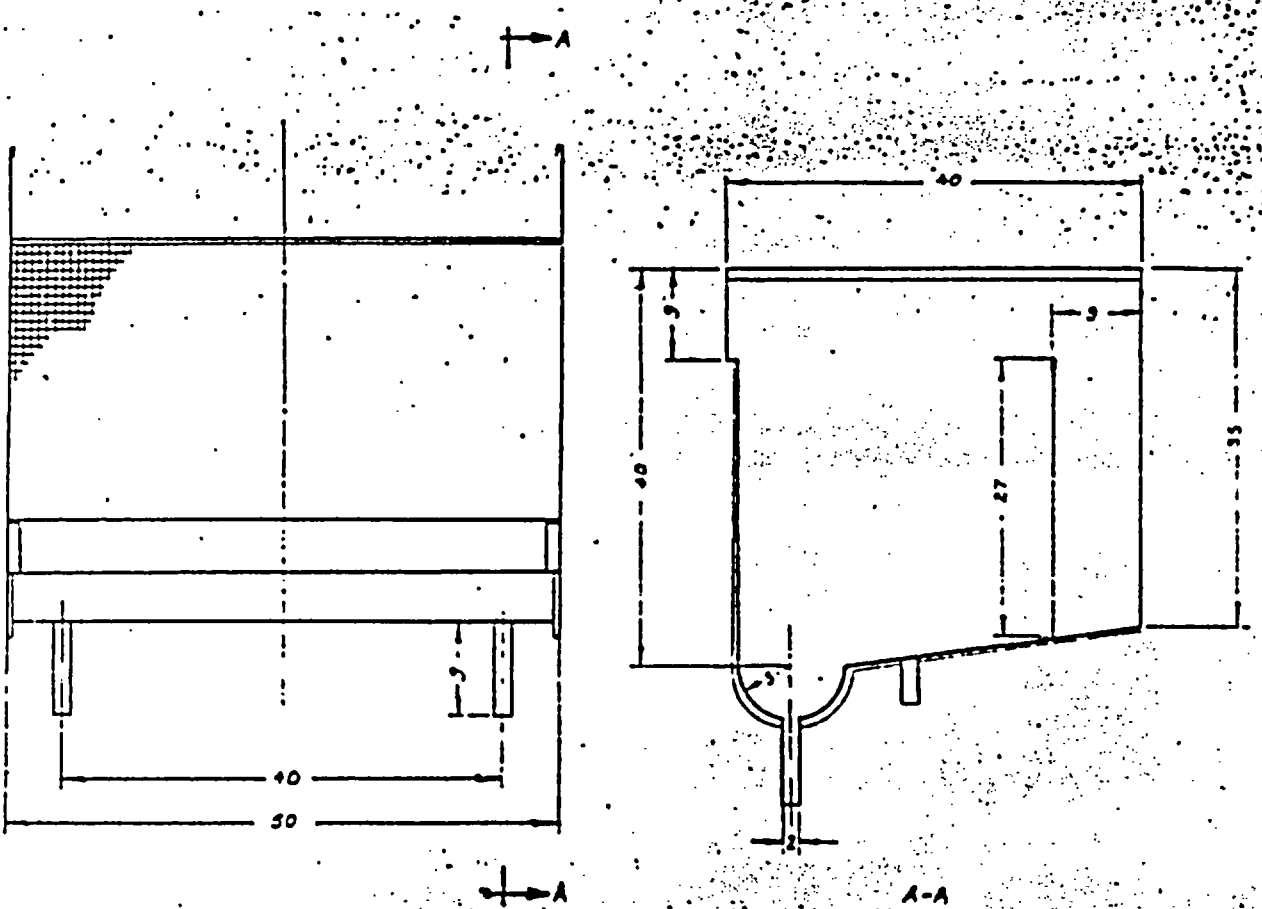
Contribution by P. Asher SCHICK, Jerusalem Israel

A modification of the Gerlach trough was designed in the Laboratory of Geomorphology of the Hebrew University, and is in use by Aharon Yair. The instrument is a double trough, with the top tray collecting overland flow and the bottom one collecting interflow. The material is thin galvanized metal. Uphill of the lower tray the soil is supported by a vertical wire netting with holes eight millimeters square. The top tray is covered by a hinged lid, mainly to prevent damage by animals. Each tray drains into two 4-liter plastic containers, connected with the help of a siphon in such a way that one container fills completely before the other begins to collect water. (Among other things, this helps to find out whether the beginning of the overland flow carries more sediment than its continuation). The bottles are emplaced in a hole in the ground in the same way as in the original Gerlach tray. The hole as well as the surface leading to the entering lip of the upper tray are stabilized by stonework and concrete.

The stabilization of the surface leading to the tray is the critical part of the instrument. The work has to be executed with great care in order to avoid damming or piping and to ensure as much as possible that boundaries of the unit strip draining into the trough will not be disrupted by the installation.



Isometric view. A Gerlach trough
Fosse de Gerlach, vue sans distorsion



Downhill view — Cross-section

A. Gerlach trough. Measurements schown in cm. scale 1/5

A gauche, vue depuis le bas de la pente.
A droite, coupe.
Fosse de Gerlach. Echelle 1/5, dimensions en cm.

Only minor repairs of the installation are required after moderately severe storms. The netting holds the soil well. After a storm of 50 mm ((2 inches) per day the interflow collected in the lower tray was quite clean of sediment.

The unit can be disassembled by sliding the top tray out. The top tray then may serve as the original Gerlach tray for overland flow only.

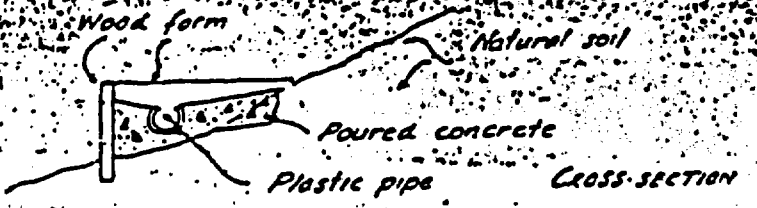
The cost of production of one complete unit was 1 £ 60 ((\$ 20). The top part costs only 1 £ 30 (\$ 10).

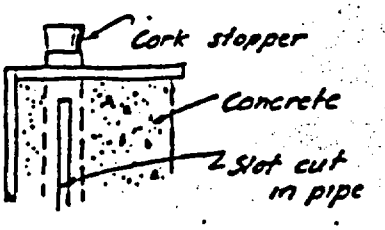
On the design of a Gerlach trough

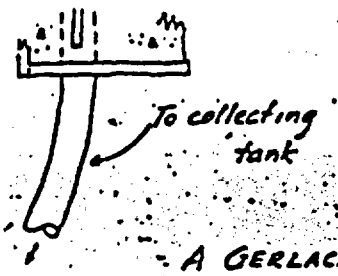
Contribution by L.B. LEOPOLD and W.W. EMMETT, Washington (D.C.)

The problem in the construction of any trough to collect overland flow on a hillslope is to get a lip tightly adhering to the natural soil surface so that the water comes off the hillslope surface on to the lip of the trough. In earlier trials we have experimented with a metal lip which was pushed horizontally into the soil of the hill, but there was enough disturbance of the soil that it was not satisfactory.

The new method that we are now using is to make the installation out of concrete. A wooden form, about 1/2 meter long and 5 centimeters high, is prepared to hold the downslope edge of the poured concrete. The upper edge of the surface being prepared is cleared of vegetation so that a slight vertical wall of mineral soil is exposed, and that forms the uphill edge of the poured concrete. Into the wet concrete there is inserted a hose which is led downhill to a collecting tank that stores the runoff and the sediment which flowed into the trap. The hose or pipe is made of thick plastic, 1 inch inside diameter. Within the concreted section there is a slot cut in the pipe to allow entrance of water and sediment. The pipe has a slight gradient even within the concreted section so that water will flow toward the collector.







Fosse de Gerlach

En haut, coupe. Bâti en bois, gouttière en ciment avec tuyau en plastique, posés sur le sol naturel.

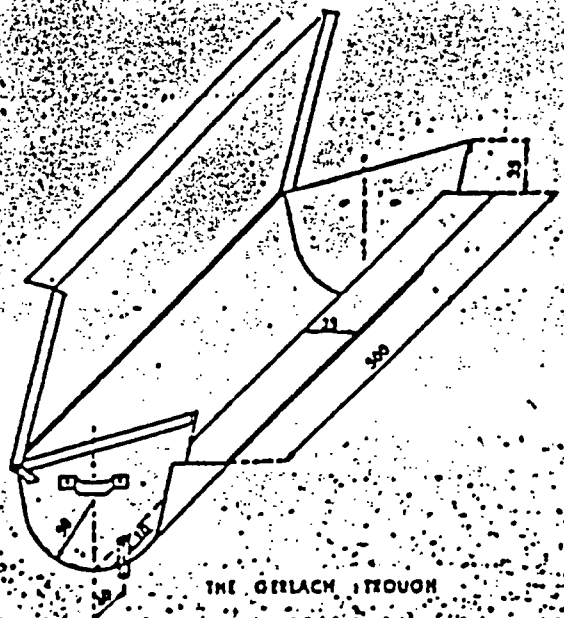
Au milieu, vue en plan montrant, vers le haut, le bouchon en liège, le massif de béton, la fenêtre coupée dans le tuyau et, vers le bas, le départ vers le réservoir.

Hillslope troughs for measuring sediment movement

Contribution by T. GERLACH, Krakow

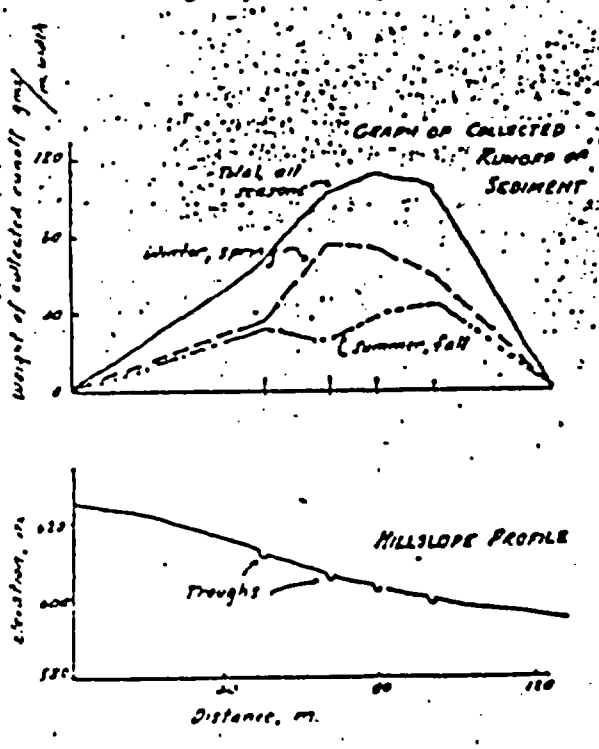
On prairies or in forests where small rills are absent we have measured the production of sediment by overland flow with the aid of zinc-plated troughs. The dimensions of the troughs are, length 50 cm, width 10 cm and depth 8 cm. The trough has a movable lid which prevents precipitation falling directly on to the trough from entering the catchment bottle. Connected to the nozzle coming out of the trough is a rubber hose and the water and sediment are thus led to a closed drum of capacity 5 to 20 cubic decimeters. There are small handles on the side walls of the trough which fit over pins driven in the ground. This allows the trough to be fixed accurately to the ground surface.

Two or three troughs are installed beside each other. The groups of troughs at various distances from the hill top are set en echelon so that they do not interfere with each other. After the troughs are installed the hillslope is mapped and described in detail.



THE GERLACH TROUGH

Appareil servant à déterminer la valeur du ruissellement sur les versants des parties et des pâturages.



SAMPLE OF FIELD DATA FROM GERLACH TROUGHS

Data from Tadeusz Gerlach

Echantillon de données de terrain données par la Fosse de Gerlach

En haut, en ordonnées, sédiment récolté apporté par le ruissellement, en grammes par mètre de section.

Le graphique montre les variations des apports : la courbe supérieure, le total des diverses saisons, la courbe moyenne, ceux de l'hiver et du printemps, celle du bas, celle de l'été et de l'automne.

En bas, profil du versant équipé et position des fosses.

Both water and sediment are collected by the trough and deposited in the storage container. After the snowmelt in spring, or after the summer storms the water and sediment are removed from the drums and brought to the laboratory. In the laboratory the water is filtered and the filters are dryed and weighed. The accompanying figure shows a sample of the seasonal variation in sediment catch in such troughs as a function of distance from the hill top.

Seismographic methods

Contribution by Frank AHNERT, Baltimore, Md.

The variation of waste cover thickness on slopes is an important element in the analysis of slope form and slope development. Conventional methods of measuring this parameter have several disadvantages. Soil augers may be stopped in their downward progress by stones before reaching the bedrock, and are often unsuitable for the detection of significant discontinuity surfaces in the waste, unless they provide an undisturbed core. Digging through the waste to the bedrock is a laborious and time-consuming exercise, may become practically impossible where the waste cover is thick, and is likely to arouse the ire of the property owner on whose land

the digging is done. To bypass these difficulties a successful attempt was made during a field study of slopes in the Appalachians of North Carolina in August of 1966, to use a portable refraction seismograph instead of the more conventional methods.

The instrument used was a Terra-Scout Model R-150, rented from Soiltest, Incorporated, Evanston, Illinois. It consists of an oscilloscope to which a geophone and a « hammer » (better described as a heavy tamper) are connected by cables. Power is supplied by a 6-volt rechargeable battery. Impact of the manually operated hammer produces a shock wave in the ground and simultaneously triggers an electrical impulse which is transmitted through the hammer cable to the oscilloscope. The latter measures the time interval between hammer impact and arrival of the shock wave at the geophone, and can be set at a sensitivity of either 0.1 milliseconds or 0.5 milliseconds. Readings are taken by visual inspection of the sweep on the oscilloscope screen (i.e. the instrument is a seismoscope rather than, as advertised, a seismograph).

The Terra-Scout can be rented for $ 270.00 per month, or bought at about $ 2,500.00. It is recommended to order a complete set of spare transistorized modules with the instrument. During our field work one of these modules failed and a replacement had to be ordered by air express freight, which caused a delay of several days.

Field operation requires two men, one to pound the hammer on the ground and another to read the oscilloscope. At each observation site, the distance between hammer impact point and geophone is progressively increased, at intervals depending upon the degree of accuracy desired, and upon the thickness to be measured. We started hammering two feet away from the geophone, then increased the hammer distance at two-foot intervals to twenty feet and from there at ten-foot intervals to fifty feet. The depth to which density discontinuities in the ground can be detected equals approximately one-fourth of the maximum hammer distance used. Since the cable connecting the hammer with the oscilloscope is 200 feet long, the instrument is capable of measuring to depths of about 50 feet.

Evaluation of the data begins with the plotting of time-distance graphs, from which the velocities of the shock wave and the hammer distances at which velocity changes occur, are obtained. These values in turn are used to compute the depths of discontinuities according to formulas given in the manual that accompanies the instrument. For layers a few feet thick, the depths computed appear to be reasonably accurate to the nearest 0,1 foot.

The refraction-seismic method yields useful results only if the density of the layers studied increases from the surface downward. It is unusable, for example, if freezing makes the surface denser than the unfrozen material underneath. Also, the data tend to be of poor quality when there are strong irregularities in the waste bedrock interface, or when the waste contains many irregularly spaced stones ; in both cases the velocity of the shock waves becomes subject to erratic variations. Another restriction lies in the bulk and weight of the instrument. The oscillograph weighs over thirty pounds, the hammer not much less. This makes it virtually impossible to operate in dense forest or brush without preparation by clearing a path.

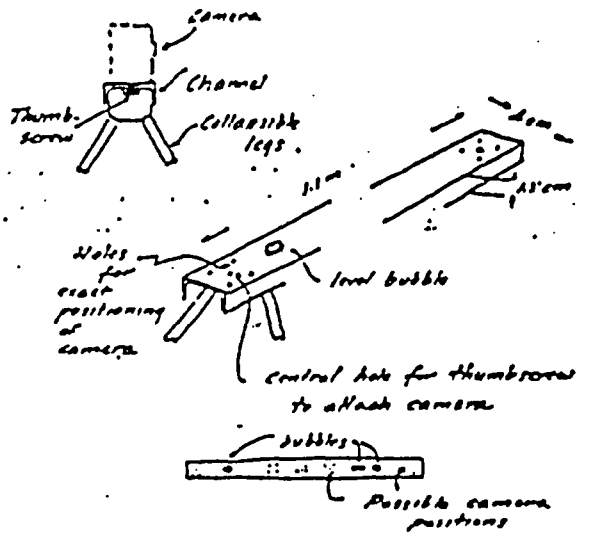
Apart from the measurement of waste cover thickness, the refraction-seismic method lends itself well also to determination of the depth of a shallow water table, or to measurement of the thickness of the active layer in periglacial environments.

Photography and Stereophotography

Contribution by R. CURRY, Berkeley, (Calif.)

A simple instrument for analysis of multiple slope processes by repeated stereophotography has been developed. The instrument is basically a piece of Duraluminum channel stock 1.1. m in length to which may be attached four telescoping legs of adjustable length from 1/2 to 1 m (see figure). The legs are threaded and easily removed from the channel stock when the instrument is to be transported. Two circular bubble levels and a standard level bubble are affixed as shown and provision is made for affixing a removable plumb-bob line near the center of the channel.

Any moderately good single-lens reflex camera can be modified for use with this instrument. Provision must be made for fixing the camera to the bar at various accurately located points along the bar's length. Four small pins about 2 mm long were set into the base of the camera body symmetrically disposed around the threaded tripod mounting hole. These pins were made to exactly correspond to small holes drilled into the upper surface of the 1.1 m bar symmetrically disposed around a large hole drilled through the bar which was aligned with the



En haut, vue en profil de la position de l'appareil photographique visé sur la poutre à pieds pliables.

Au centre, vue perspective, avec les trous et le niveau à bulle.

En bas, vue de dessus de la poutre, avec les niveaux à bulles et les trous pour visser.

tripod hole on the camera so that a single thumbscrew could be used to tightly fix the camera to the bar.

The system should be aligned so that when the channel stock is level, the camera may be mounted in the exact center of the bar and an exposure taken with the film plane parallel to the length of the bar, and then the camera may be moved to another mounting hole and fixed to the bar for a second exposure. All mounting holes should be aligned with real or improvised cross hairs coinciding with a fixed point on the horizon. Fiducial marks to locate the principal point on the photographs can be made by filing accurately located nicks along the frame of the camera focal plane so that they will show up on the negative but will not occlude any portion of the actual picture frame as the fiducial marks in aerial photo cameras do.

In use, the instrument is located at a hopefully stable marked spot by plumb line, and compass orientation of the axis of the 1.1 m bar (to the camera optic axis) and the positive or negative declination of the camera optic axis from the horizontal are measured to 1° and recorded. With adjustable legs, the instrument can be set up on slopes up to 25° but the height of the instrument above the marked spot must be noted so that it may be set up in similar manner again. An exposure is made with the camera at the center of the bar and then it is moved to the right and left for subsequent exposures. For slope processes affecting areas 5 to 100 m distant from the camera station, the camera should be mounted so that right and left exposures are taken on one-meter centers. For detailed close-up work, 20 cm and 7 1/2 cm centers have been used. During one set of exposures at a given site, scaling rods, of known length, should be placed at a known distance from the camera as near the center of the field of view as possible.

Quantitative analyses of changes over the entire field of view of the photos are carried out by standard photogrammetric techniques. Qualitative analyses may be made by stereoscopically viewing pairs of photos in which one photo was taken at a different time than the other, or by projecting a negative image of a photo taken at one time onto a positive print of a photo taken at another time from the same camera position. In this latter case, neutral gray tones will be seen wherever there has been no motion but areas that have changed will be evidenced by light and dark «contrast rings» centering around the area of greatest motion perpendicular to the camera axis.

The advantages of this instrument for slope studies are that it is lightweight (circa 1 kg exclusive of camera), inexpensive to build (the camera is still perfectly usable for all other purposes), and great versatility in examining whole slope processes and random events when compared with optical surveys of fixed points, painted lines, etc. Disadvantages are lack of accuracy at distances greater than 20 × the base length from the camera (± 2 % with 35 mm format at 33 × the base length), and the necessity for repeated photos to be taken at the same time of day on or near the same calendar date. With carefully placed scaling rods, the location of a point 10 m from the instrument may be determined to within 1 cm with 55 mm focal length lens on 35 mm film.

On repeated photographs

Contribution by R. CURRY, Berkeley, (Calif.)

Most frequently, slope studies involving comparison of photos taken 50 to 100 years apart at a given site cannot make use of the exact same camera for both exposures. Where the same old camera is not available for current work, one can still make accurate photographs from which much quantitative data can be derived by using a camera with the same ratio of lens focal length to maximum diagonal negative dimension as was used in the older exposure. This ratio can be

computed for old photographs by field measurement of objects within the photographs or, in many cases, by scaling distances between prominent landforms shown in the photos directly from accurate topographic maps. If the ratio cannot be directly computed, it may be approximated by assuming that the focal length of the old camera lens was between one and two times the maximum diagonal negative dimension. Of 2000 large-format landscape photographs taken in western United States between 1875 and 1900, I have found that the focal length of the lens is most often 1.7 to 2.0 times the maximum diagonal negative dimension.

Where the photo site has been accurately relocated and the focal length ratios are approximately the same, exposures taken with modern 35 mm cameras may be enlarged to the size of the old photos and they may be compared by viewing them under a pocket stereoscope. If the current exposures have been made at such a time of day that shadows in both new and old photos are similar, many subtle differences can be detected.

On Methods of measuring sheet wash and rill erosion

Contribution by Otakar STEHLIK (Czechoslovakia)

Regular daily observations of the quantity of load in rivers will be carried out by the Institute of Hydrometeorology in 19 places in the Labe River basin, in 10 places in the Odra River basin, 60 places in the Danube and 2 places in the Vistula River basin. In addition short-term observations of load trasport in typical small river basins were started in 1965 at 16 selected locations. These deal primarily with the quantity of load during spring and summer rainstorms.

The Institute of Geography of the Czechoslovak Academy of Sciences initiated a network of observers for the territory of Czechoslovakia to observe and record the extent of damage caused by rain storms on agricultural land. Within 3 days after the damage occurs the Institute of Geography is informed. This information makes it possible to choose areas where the development of rills and sheet erosion is especially important.

We have attempted to use aerial photography to show the development through time of erosion features. The repeated photographic record of the same object provides information relevant to the development of erosion phenomena.

For special purposes we constructed a radio-operated airplane model with a parachute wing which contained a camera that could be released from the model on a signal from a ground-operated radio. The model plane can ascend to an altitude of 300 m, it has a minimum flying speed of 2 m/sec, and can stay aloft for 20 minutes. Its flying range is about 800 m from the control radio. With a camera with an f-8 lens utilizing a negative 6 cm × 6 cm in size the relief of an area of 16 ha can be recorded in one picture during a flight at altitude of 300 m. It is possible to suspend a motion camera to the fuselage of the airplane model and it will be capable of taking stereoscopic views suitable for measuring the dimensions and forms of erosion rills and other micro relief features.

INCLINOMETERRS OR T BARS

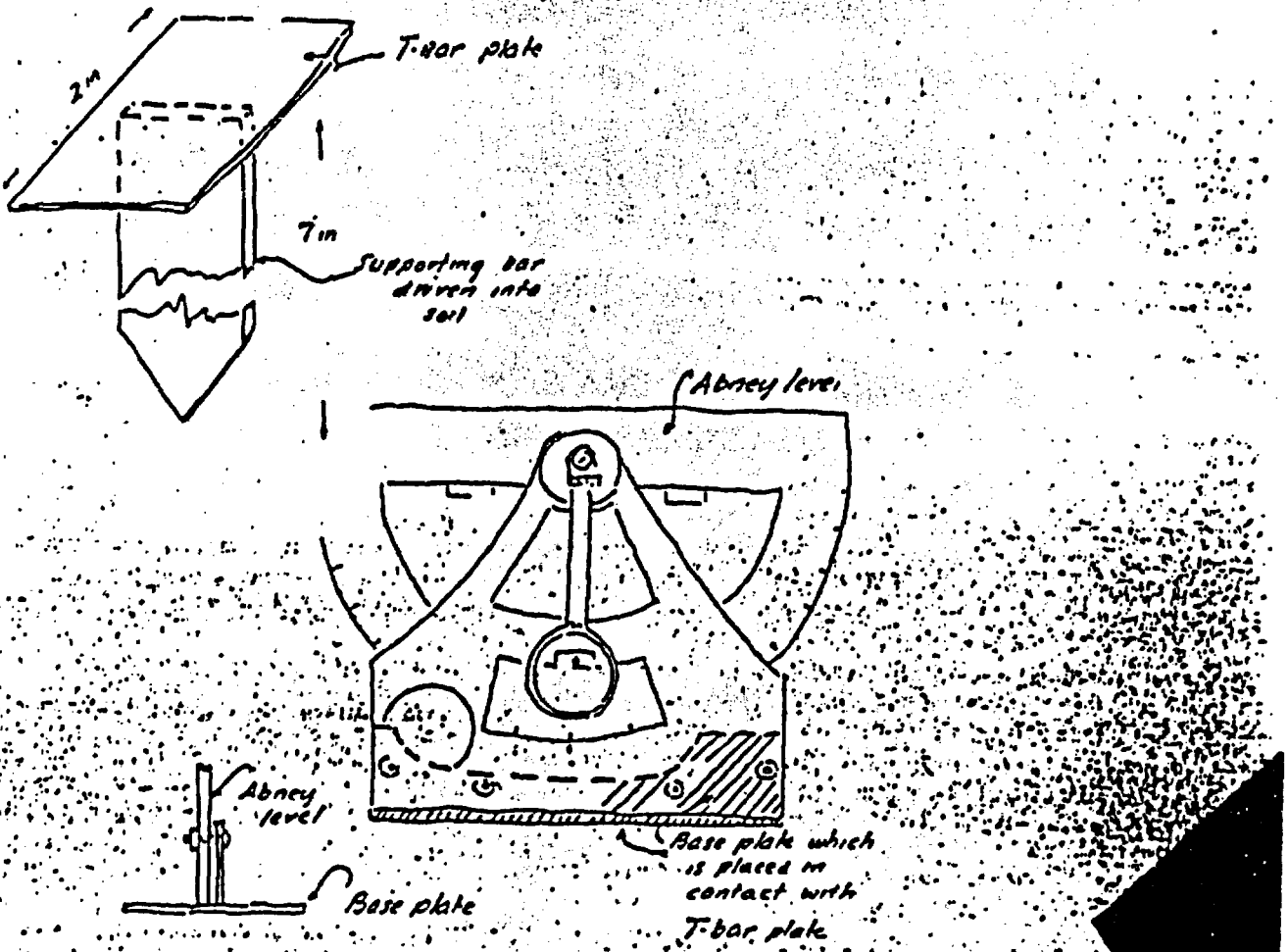
Contribution by R. EVANS, Sheffield (U.K.)

The T-bar is an instrument devised to measure movements in the upper few inches of the soil which result from the effects of wetting, drying, frost, gravity, etc. The instrument described here is a modified form of the « T-peg » first used by Kirkby and later by Slaymaker. The amount of movement of the soil is expressed by the angular displacement of the T-bar and from this a crude linear measure of movement can be calculated. Besides the T-bar, therefore, a device is also required for measuring the angle of tilt.

The instrument illustrated here is made of readily obtainable and inexpensive materials and is of very simple design (figure A). A steel plate (2 × 1.5 × 0.05 inches) is brazed to a steel blade (1 × 0.25 inch) which in the original design was 7 inches in length. The thickness of the plate is such that it is as light as possible but does not distort on brazing. The T-bar is painted to protect it from rusting.

The length of the blade now in use is 7 inches, which provides 6 inch penetration into the soil and 1 inch clearance. This clearance allows the bar to be used on slopes of up to approximately 35 degrees provided the vegetation cover is low.

As a result of current experiments in the laboratory it now appears that the length of the blade should be shorter, for example, 4.1 inches. This is because the soil becomes more compact and stable with depth and this



Position du niveau Abney sur la tablette portée par un piquet enfoncé dans le sol

inhibits movement of the T-bar. But if the blade is shorter than 4 inches it becomes relatively top-heavy. Further experimental work is being carried out to improve the design and to lighten the instrument.

The device for measuring the angular movement of the T-bar consists of a large Abney level (The Stanley Telescopic Abney Level, manufactured by W. F. Stanley & Co., Ltd., London) from which the heavy viewing column has been removed and which reads to 1 minute of arc. This mechanism is rigidly attached to a light alloy base plate (figures B (i) and B (ii). It has been found that because of the light weight of the level the area of the T-bar plate should not be of smaller dimensions than those suggested here, since by reducing the area of contact between the level and the plate friction is lowered and the clinometer cannot be kept still for reading.

SHIFT OF ROCK FRAGMENTS

Contribution by J. DEMEK, Brno (Czechoslovakia)

1. The following kinds of experimental areas were chosen :

a) with essentially identical forms

b) with the same and even different geological structure

c) with the same and even different altitude m.s.l.

d) with various vegetation cover, namely:

da) spruce monocultures (Picea excelsa)

db) grass areas within the forest zone

dc) in the area of Alpine meadows (above the timber line)

2. The experimental areas were mapped topographically in detail on scales of 1:250 -

1:500. Detailed contour plans were made. The original drawings of the plans are on plastics so that they assure the dimensional stability. The chosen territories cover an area of 2,5 - 12, 5 ha.

3. In the chosen territories detailed geological, geomorphological and biogeographical research was carried out and respective geological, geomorphological and biogeographical plans were compiled. Even special observations such as mechanical analyses of products of weathering, of soils, clayey minerals, the bio-mass, the root system, etc.., were carried out. Even mesoclimatic measurements are to be realized.

4. The polygonal tension on the perimeter of the territory chosen was measured in detail in the experimental areas. The individual polygonal points were fixed carefully by means of steel tubes and concrete. Besides, fixed points, immobile indeed, were established on bedrock outcrops.

5. A great number of blocks were levelled exactly as to the angles and the distances from the point of the polygonal tension and from the fixed points on the bedrock outcrops. A great number of blocks were measured by means of a tacheometer with the angle accuracy of 30" and with an accuracy to distance of ± 7,5 cm and to height of ± 5 cm. Farther blocks were measured from the posts (polygonal points) by means of a steel band with the accuracy of ± 1 mm. The height position of these blocks was determined by surface levelling with the accuracy of the order of ± 1 mm.

6. Rock fragments of equal and various size were measured :

a) those lying on the surface
b) partly buried in sediments and weathered mantle
c) projecting only with a small part over the surface of the terrain

7. The experimental areas were established on slopes :

a) where fragments occur but sporadically
b) where fragments occupy 30-40 % of the area
c) covered with block fields (50-100 % of the area covered with fragments)
d) where stone polygone occur
e) where block streams are developed

8. Besides the levelling of individual fragments lines parallel to contour lines were established with color in block fields and block streams. The lines are 10 - 30 m long. The ends of some lines are fixed in bedrock outcrops. Other lines pass only on free lying fragments.

9. The extent of slope movements will be established :

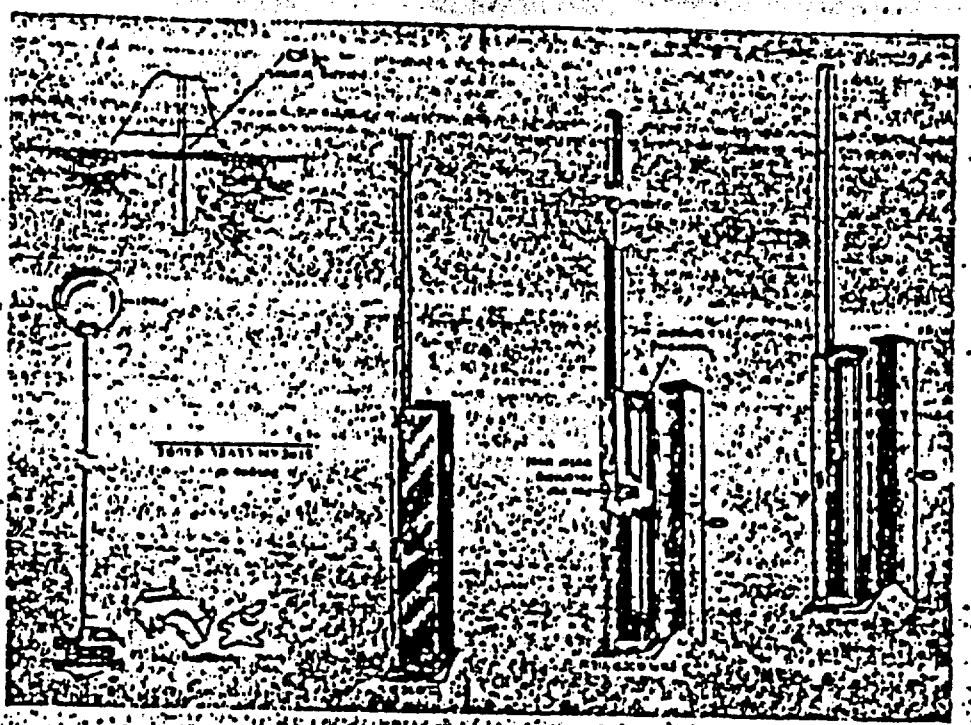
a) by repeated measuring of the points levelled exactly ; the repeated measurements are planned to be realized every 5 years
b) by observation of the lines ; the observations are carried out in spring and in autumn and serve for giving precision to the periodicity of the movements.

On preferred orientation of stones

Contribution by Sten RUDBERG, Goteburg (Sweden)

Measurements of long axes of stones have been used by the author in till covered areas to show : 1) whether mass movement has occurred ; 2) the thickness of the moved layer. The surface layers normally show a preferred orientation of stones in the direction of the slope; more pronounced in till rich in fines, but noticeable also in areas poor in fines. In lower layers the slope direction orientation of stones is gradually weaker, and grades towards the direction of the last ice movement. To show this tendency different sets of measurements are made at different depths, e.g., in the layer 0-10 cm, and in the layer 0,45-0,55 cm. In each set a hundred stones are measured as to their direction in a horizontal projection. The results are shown in « rose diagrams ».

The investigations, which are spread also outside the mountains, demonstrate that the mass movement, indicated by the preferred orientation of stones in the surface layers, is not restricted to specially cold climates or to areas where the surface layers have been influenced by a cold climate of the past. The depth of the moved layer is normally at least 0,5 m. The orientation in a vertical plane could also be investigated. It would probably show some sort of imbrication. As to the complications, it is necessary to use stones which do not touch each other. The method is restricted to areas wich are not too rich in stones and boulders.



Limnigraphe, ouvert à gauche, décortiqué au centre, pour montrer la plume, le cylindre et le flotteur, en bas et à droite, installé

The instrument as described above has a potential range of approximately 5 feet. The limitation of range is due to the increasing weight of the alloy rod as longer lengths are used. Depending on the channel under study a wider tube and larger float could be utilised although this will also increase the cost of the instrument. The limitation of reading as regards low flows depends on the size of the float. Thus, for a float 1.5 ins. in diameter, the instrument should not be used for depths below approximately 3 ins.

The instrument described provides accurate information concerning maximum and minimum water levels while remaining simple in design and inexpensive in construction.

Crest Stage Gauge for narrow cross-sections or small pools.

This instrument is designed for cross sections under 5 ft. in width. It is both easier to construct and cheaper than the larger gauge and may thus be used in greater numbers. The following materials are required for construction.

1) Aluminum tubing (1.125 ins. internal diameter) 6 ins. longer than the height range required.

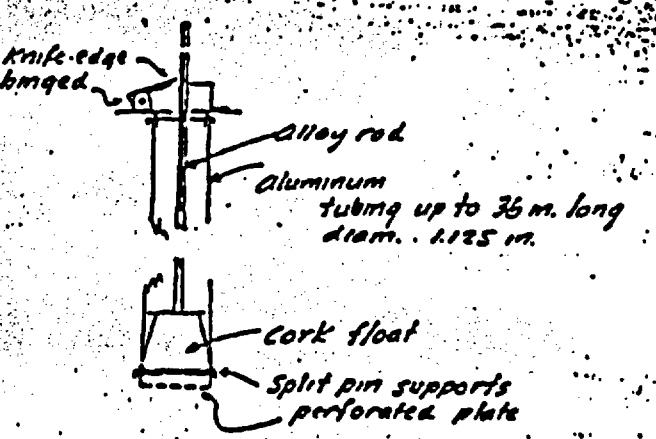
2) A length of straight alloy rod (0.0625 ins. in diameter) 2 ins. longer than 1).

3) Float of cork of maximum di
1 in.

4) Steel blade.

5) Additional steel fittings and co
(made up as required).

Figure 2 shows the main features of the gauge. The float supports the alloy rod and both are enclosed in the aluminum tubing.



TWO TYPES OF CREST-STAGE GAGE

FIG. 2. — Deux types de limnigraphe à maximum. *En haut, à gauche*, couteau sur une charnière. *A droite*, dans l'ordre : tige d'alliage, tube d'aluminium pouvant atteindre 36 m de long, flotteur en liège, barre à fente soutenant une plaque perforée.

The lower end of the tubing is covered with a steel plate with only a few small perforations to allow the water in and out to decrease the effect of turbulence.

The upper end of the tubing is covered by a steel plate through the center of which the alloy rod protrudes. Brazed onto the cover is a fixed right-angled fitment and a hinged plate whose end nearest the alloy rod is sharpened. Thus, as the water level raises the cork and rod, the hinged plate lifts and allows the rod to rise. However, when the water-level falls the rod is trapped between the knife-edge and the fixed angle-plate. The instrument is then read by measuring the length of the rod above the base plate. This is done by resting a rule on the base and sliding a horizontal arm down the rule until it touches the top of the rod. The weight of the alloy rod considerably reduces the buoyancy of the cork so that this gauge is less sensitive than the larger instrument.

Installation and operation.

The gauge is attached to a frame of slotted angle steel (Dexion, Ltd.) which is fixed firmly in the bank. Once installed the only necessary attention is the regular oiling of the hinge. The knife-edge should function properly for many months without resharpening. It has been found that vibration of the instrument due to water-flow or wind does not disturb the reading.

Although the instrument described above has a range of probably no more than 3 feet it is felt that it is very suitable for use in small pools whose levels can be rated to natural or artificial weirs. Its great advantages are its extreme simplicity, cheapness and accuracy. A greater height range can of course be achieved, using wider tubing and a larger float.

An instrument of similar design but with the knife-edged blade hinged downwards, to show minimum flow, has been tested but it was found that with the rising stage the buoyancy of the cork overcame the frictional resistance of the knife-edge and it has not proved to be effective.

Crest stage gage of U.S. Geological Survey

Contribution by L. B. LEOPOLD

A galvanized iron pipe about 2 inches in diameter but to a length of 3-6 feet, depending on how much rise in water level is expected. The pipe is threaded at each end and furnished with a screw cap at top and bottom. Several small holes are drilled near the bottom of the pipe to allow entrance and exit of water. A hole is drilled in the cap at the top to allow exit of air.

A few cc of ground cork or other light, floating material is put at the bottom of the pipe when in a vertical position. The cork may be put in the base cap before the cap is screwed on or simply poured in the top of the pipe.

A wooden stick just the length of the pipe is put inside of it. The stick stands on the bottom cap and is prevented from floating upward by the top cap.

The pipe is attached in a vertical position to a tree or bridge abutment. The bottom cap is slightly above water surface at low flow.

SUSPENDED SAMPLER

Contribution by P. Asher SCHICK, Jerusalem (Israel)

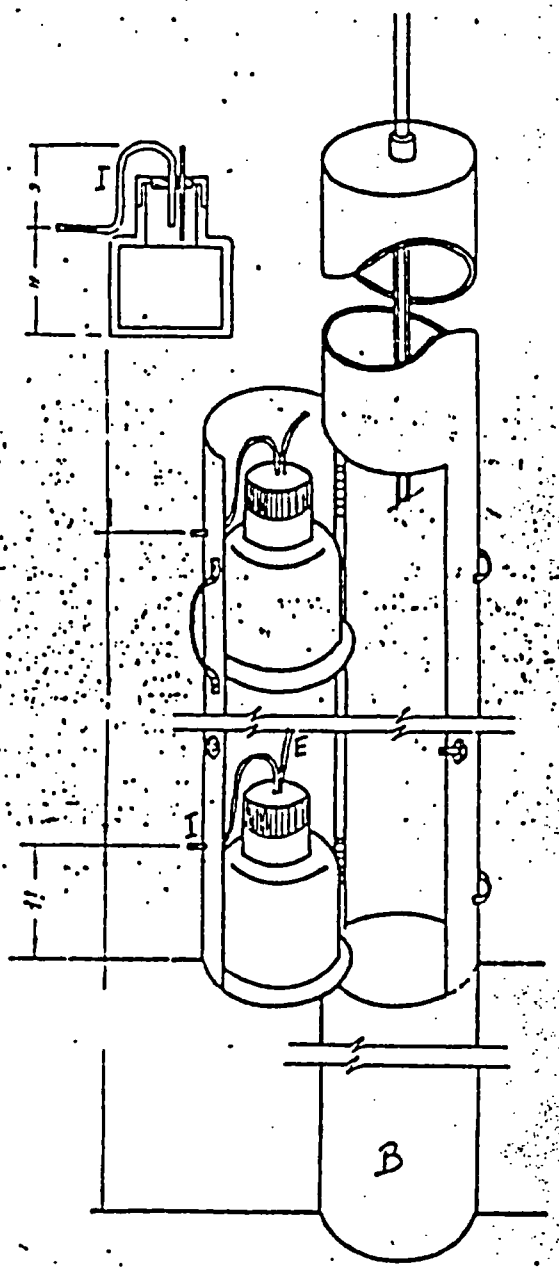
This is a modified use of the standard automatic single stage sediment sampler used in the United States. It was designed primarily for desert streams where personnel is scarce and floods are very violent and short-lived.

Three types are in current use : type « Hayim 4 » with 8 bottles ; « Hayim 5 » with 4 bottles ; amd « Hayim 6 » with 2 bottles. All types are housed in a 6-inch diameter iron pipe, thickness 4 mm. The water intake pipe I is brass, 9 mm outer diameter, 7 mm inner diameter. The air exhaust pipe E is plastic, diameter 6 mm. The difference in elevation betwen two successive intakes is 25 cm. All types use standard one-liter plastic bottles.

Type « Hayim 4 » (8 bottles) is in use in large stream channels where a stage of 2 meters is likely. It is usually fastened to a bridge pier, and the base B is absent. The housing for the separate air exhaust pipes H is also mostly absent, and the pipes are fastened individually to the side of the bridge. Their end is turned down to prevent direct rain from draining there from the bridge.

Type « Hayim 5 » (4 bottles) is in use in medium streams where a stage of one meter is likely. It is usually emplaced in a hole in the channel bed up to one meter deep, and secured with big stones and concrete tied to cross iron bars going through holes across the base part of the pipe. The exhaust housing is 60 cm long. The base B is one meter long,

Type « Hayim 6 » (2 b[illegible]s) is in use in small streams, often in ec[illegible]chelon batteries of two or three instruments if fine sampling,



Lengths in cm.
Préleveur de suspension (longueurs en cm)

i.e. one sample for every few centimeters of stage, is required. This type has no base, and the exhaust housing is 30 cm long. The instrument is fastened by bolts to a stake at the downstream side of the pipe. The stake is driven into the channel bed.

[illegible] usual 9 cm. In [illegible]t case a variant of type « Hayim 6 », o[illegible]ing upwards, enables the emplacement in such an elevation that the bottom bottle is below channel bed, and its intake only a few centimeters above it.

On the inside of the pipe a white or yellow strip is painted vertically. This serves as a crest stage gauge.

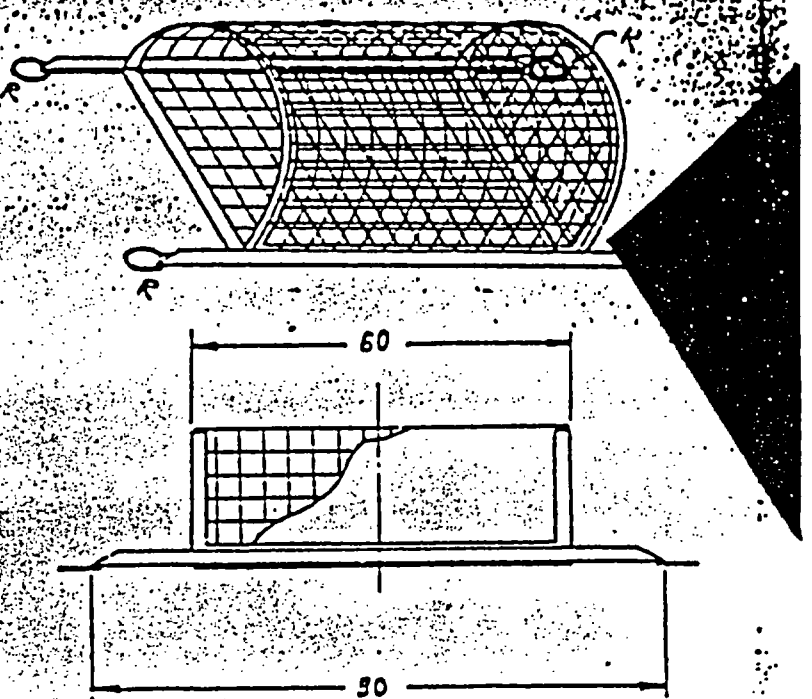
The instrument holds well against vandals, with the possible exception of the uncovered exhaust pipes in type « Hayim 4 ».

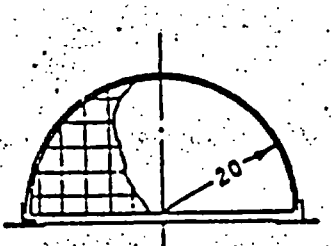
Production prices are : « Hayim 4 » - IL 120 ($ 40) ; « Hayim 5 » - IL 100 (about $ 30) ; « Hayim 6 » - IL 65 (about $ 20).

BEDLOAD TRAP

Contribution by P. Asher SCHICK, Jerusalem (Israel)

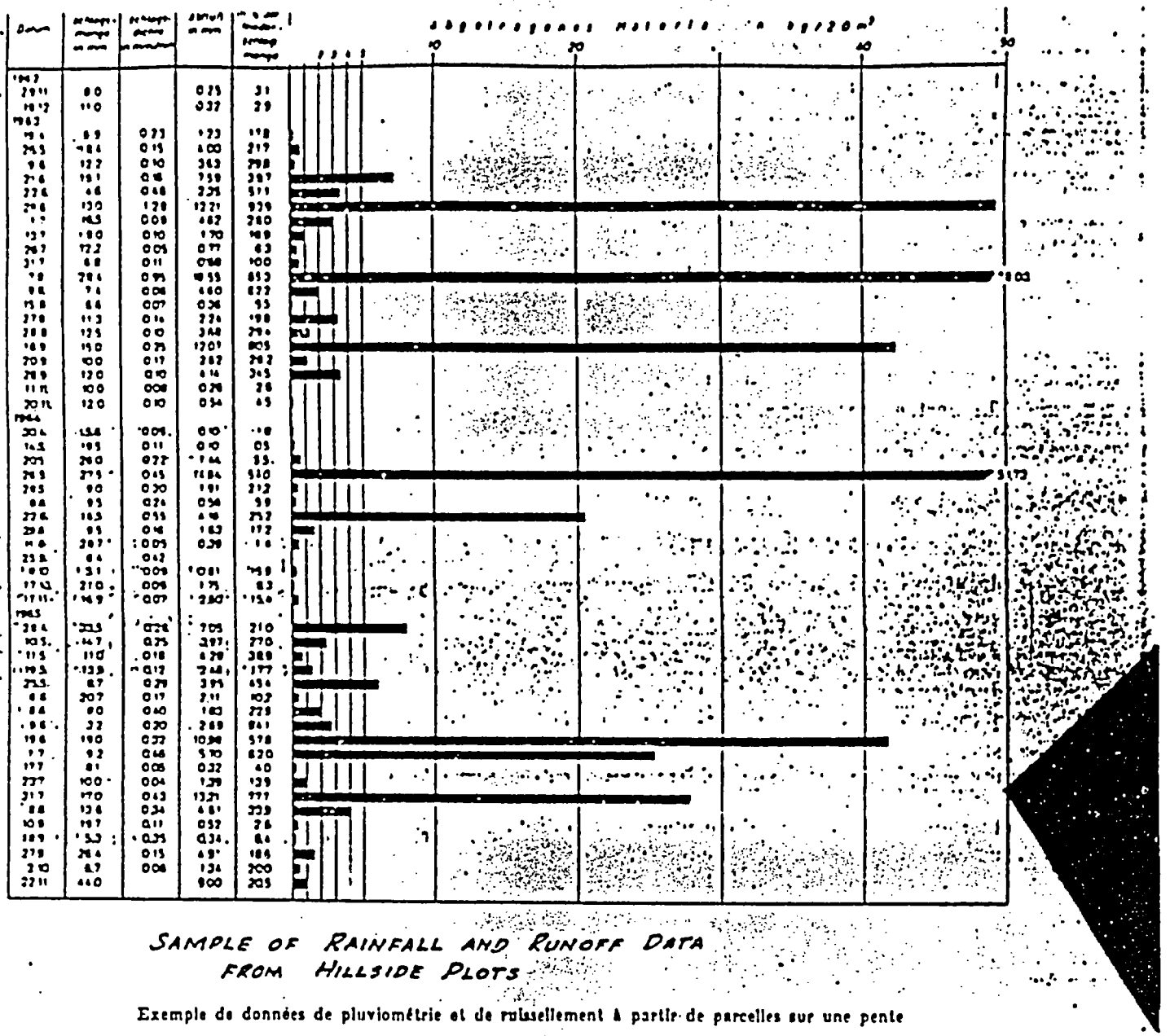
A simple trap to collect bedload moved by flash floods in ephemeral streams is built of an iron frame with a galvanized wire netting.





A Bedload trap Lengths in cm.

Trappe à sédiments de fond (longueurs en cm)



SAMPLE OF RAINFALL AND RUNOFF DATA FROM HILLSIDE PLOTS

Exemple de données de pluviométrie et de ruissellement à partir de parcelles sur une pente

Colonnes, dans l'ordre :

Date.
Intensité des précipitations en millimetres/minute.
Coefficient d'écoulement.
Précipitations en millimètres.
Ecoulement en millimètres.
Matériel entraîné en kilogramme par 20 mètres carrés.

On rainfall simulation

Contribution by Rorke BRYAN, Sheffield, U.K.

A compact rainfall simulator has been designed for use in laboratories where fall-height is limited. Experiments had shown that a water-drop of 4.0 mm diameter could attain 83 % of the terminal velocity of a raindrop of the same diameter in a fall-height of 1.66 m, and the instrument was based on this fall-height. The unit is built around a framework of angle steel measuring 216 × 121 ×

63 cms. At a height of 38 cms in this framework a 121 × 63 × 15 cm galvanized tank is suppported on a rubber lined mounting. At one end of this tank a 38 × 38 × 10 cm tray is mounted, fitted with movable splash screens. This tray is mounted on a pivot and by use of a worm assembly its inclination can be varied from - 1° to + 32°. The base of the tray is angled to form a gutter leading to a 2.5 cm exit pipe. Inside the splash tray a removable 30 × 30 × 10 cm sample pan is mounted on raised studs. In this pan a 7.5 cm deep sample is placed above a 2.5 cm layer of glass beads and filter paper which prevent the sample sliding at high inclinations. The base of the sample pan is perforated to allow free drainage of the soil sample. Soil splashed and washed off the sample passes with the runoff through the exit pipe to a container beneath the galvanized tank. A separate drainage pipe in the galvanized tank carries away water falling outside the splash tray.

A number of commercially obtainable spray heads were tested, but were found to be unsuitable. Subsequently a series of spray units were built out of 9.5 mm diameter copper piping. The unit finally incorporated consists of two pipes set horizontally in staggered formation, from each of which six 1.25 cm lengths of 4.7 mm diameter copper piping project upwards. The ends of these short lengths are brazed, then drilled with 1/64 th and 1/32 nd inch drills. This gives two banks of jets of different sizes which produce two ranges drop-size. The 1/32 inch jets give a range from 0.84 mm to 3.98 mm diameter, while the 1/64 inch jets give a range from 0.67 mm to 2.87 mm diameter. From the jets water is projected upwards in an arc the apex of which is 1.66 m above the surface of the soil in the sample pan.

The 9.5 mm diameter copper pipes are brazed at one end, while water is supplied from mains through polythene piping at the other end. The pipes are set in greased « Nylotron » bearings so that they are free to rotate. The actuating mechanism for rotation is a piston and bell-crank linkage driven by an electric motor geared to 6 r.p.m. The mechanism rotates the pipes through an arc of 5° allowing the rainfall to cycle on and off the sample six times per minute, giving a rainfall intensity of 5 inches per hour.

The steel framework is sheathed on three sides by sheet aluminum, while a perspex screen on the fourth side allows observation of the sample. A 71 × 71 cm door on one side allows access to the sample, and also serves as a rainfall shut-off mechanism. A splash-hood built above the main framework to a height of 46 cms also serves as a datum for adjustment of the apical height of the water arc.

The testing of soil samples on the rainfall simulator follows a standard procedure, which the soil sample is first air-dried, then passed through a 6.35 mm diameter sieve. Each sample is first subjected to a 30 minute period of rainfall, then after an interval of one hour, to a one-hour period of rainfall. After a further interval of 15 minutes, the sample is subjected to a final hour of rainfall before drying under infra-red lamps. Soil removed from the sample is collected, and after separation from runoff is oven dried and weighed.

This instrument was designed and built by Mr. C. Fletcher, Senior Technician in the Department of Geography, Sheffield University, to comply with specified research requirements.

OTHER INVESTIGATIONS

Slides and Mudflows

Contribution by Th. PIPPAN, Salzburg.

By collecting numerous data from historic and present sources a possibility is opened to trace processes of slope development through long periods of time and to comprehend them quantitatively to a certain degree. Slides and mudflows as the most important factors of recent relief forming have been studied in the Alps of Salzburg. To comprehend their effects as to quantity, information has been collected from the River Control Authorities, the Austrian Federal Railways, from scientific papers, newspaper articles, and from the Record Office covering the period from 1567 to 1961. In this way more than 100 items concerning slides and mudflows have been filed. The author marked the localities at which such processes occurred by symbols on a map of the Federal Country of Salzburg (1). This way the areas in which mass movements have been checked rather often stand out conspicuously. Considering the geological conditions of these places is could be stated that such processes show a maximum recorded

(1) PIPPAN (Th.), « Beiträge zur Frage der jungen Hangformung und Hangabtragung in den Salzburger Alpen », *Nachrichten d. Akademie. der Wissenschaften in Göttingen. II. Mathmat.-Physikal. Klasse no.* 11, Jahrg. 1965, pp. 163-183.

frequency where soft, tectonically shattered, thinly bedded to foliated rocks as slate and phyllite occur, which is the case at the northern edge of the Hohe Tauern and in the Palaeozoic Greywack Zone. At places where permeable limestone is located upon impermeable slate or phyllite which rocks, when intensively soaked by rains provide a sliding chute, mudflows and slides develop easily. Such conditions prevail at the southern slopes of the High Calcareous Alps above the Greywacke Zone.

From the exploitation of more than 100 data from the period between 1794 to 1961 it resulted that a total identifiable mass of about 15,5 mill. cbm has been moved during this time. The highest values of rock waste transported by slides and mudflows occur where large screes at the foot of rock faces are ready to be removed, as in the High Calcareous Alps or a considerable reservoir of fluviatile loose sediment is available as for example the Riss-Würm Interglacial gravels at the slides of Embach E of Zell am See. In the soft phyllites at the northern margin of the Hohe Tauern too a vast quantity of scree develops in a short time.

Investigations as described above could be extended over additional areas and exploited by comparative research.

On engineering-geological survey of landslides in Czechoslovakia

Contribution by Jaroslav PASEK, Jan RYBAR,
Prague.

The study of landslides has a long tradition in Czechoslovakia. On our territory there exist exceptionally favorable conditions influencing the development of landslides. The areas of Cretaceous and Neogene deposits, volcanic mountains, and lignite basins are all affected by landslides. Most commonly, however, landslides occur in the Flysch sediments of the Carpathian System.

Some heavy disasters caused by landslides, the last and largest one in Handlová in 1960, showed the necessity of a preventive survey of all Czechoslovak landslide areas.

In the years 1962-1963 the registration of all important landslides and landslide areas was undertaken. Field research was carried out by about 30 research workers from several engineering-geological institutes on the basis of prepared methodical instructions. More than 9000 landslides in a total extent of nearly 600 square km/i.e. 0,47 % of the Czechoslovak territory were ascertained. Every landslide was entered onto the topographic map 1 : 25,000 in given colors and symbols. The mapped landslides were numbered and their description was filed on registering cards containing the most important data on the slide, as its situation and type, the geologic, geomorphologic and hydrogeologic features. The results of this research - the maps and the register - are deposited in the Central Geological Archives (GEOFOND) in Praha and Bratislava and serve as basis for country planning and for the design of constructions.

The landslide registration was followed by a systematic thorough investigation of the problems connected with the origin and development of landslides. This task was pursued by the Engineering-Geological Department of the Geological Institute of the Czechoslovak Academy of Sciences on the following lines. Several typical landslide areas were chosen in differing geological units for continuous investigation. This was accompanied by an evaluation of the plentiful data that were entered on the registering cards during the registration, and by the study of some theoretical problems in the laboratories.

The field research is based on the engineering-geological mapping on the scales 1:10 000, 1 :5 000, 1 :2 000, or even on lesser scales. If possible, aerial stereoscopic photographs are made use of. The results of the mapping are supplemented by geodetic measurements that enable to obtain longitudinal and transversal sections of the area. Surficial movements are geodetically measured on all the investigated slopes. The geologic features and the mode of disposition of the slide masses are studied in test pits or bore holes and by geophysical methods.

Investigations of the deformation of shores of future water reservoirs in areas of weakly consolidated clayey sediment have also been started.

In Tertiary clayey sediments fossil slope movements, exposed in the walls of opencast coal mines, are studied to compare them with recent slides.

The influence of climatic factors, as well as the changes in the physico-mechanical and geo-electrical properties of rocks and their dependence on the mineralogical and petrographical composition are also investigated.

Slope movements and recent uplift

Contribution by Th. PIPPAN, Salzburg

In areas of recent uplift, as in the Narrows of Taxenbach in the Salzach Valley E of Zell am See where tectonic movements have been active since the Preglacial slope and river bank slides, mudflows, slope pressure and rock falls happen frequently. Such processes are indicated by tilted and stilted tree trunks at moving slopes as in the slides area of Embach, by bulges at the valley sides produced by sliding, by sagging of the federal road checked by the position of ancient curbstones now located 4 m below the present road level, and by the shifting of berms (made of concrete) up to 1,5 towards the bed of the Salzach. Further symptoms of recent slope movements are fissures and soil subsidence at the upper edge of the slides of Embach. The annual transport of the gravel mass at the foot of this unsettled area attains some dm. By the advance of the sediment body towards the Salzach its bed has been reduced by half of its original width. Morphologically the recent uplift area of Taxenbach is marked by parmenent fluvial downward erosion, slope disturbance, over-steepened valley sides even in soft rocks and by a narrow gorge section of the valley.

According to the technical report 1961 of the River and Avalanche Control Authority for the Lower Pinzgau in Zell am See the Salzach gauge at Lend showed an average annual downward erosion by 5,3 c.m. from 1886 to 1925 and a permanent erosion of 2,1 cm since 1911. At the uplift center of Embach this value attains up to 4 cm, at the foot of the slides up to 5 cm.

On climatic control of mass movements

Contribution by Th. PIPPAN, Salzburg

Generally south-facing strongly desiccating slopes as well as valley sides exposed towards rain-wind from west and northwest and located above the timber line are especially attacked by denudative processes. This fact points to the importance of precipitation for sliding and mud flows. These relations have been investigated by tracing 107 cases covering the period from 1567 to 1961. As far as possible the amount of precipitation for the days on which such mass transport occured has been checked for the place concerned or the nearest climatic station. Generally it could be stated that mudflows and slides often are associated with heavy rains caused by thunderstorms or eventually with permanent rains which produce floods. The comparison of the graph of precipitation with that of mudflow activity (Pippan Th., 1963, p. 178, fig. 8) shows that the maximum of this process occurs in the month with the maximum amount of precipitation which is July, when 15 % of the annual precipitation and 28 % of mudflowing are reported. A secondary maximum can be stated in August. These two months are often marked by thunderstorms with heavy rains and sometimes by permanent precipitation and floods. Usually mudflows occur in summer after a hot dry period during heavy rains caused by thunderstorms.

On slope development in cirques and trough valleys

Contribution by Th. PIPPAN, Salzburg

The tectonic and lithologic control of cirque and trough wall development has been investigated by comparative studies in the mountains of the English Lake District and Norway, in the Bohemian Forest of Germany and Austria and the Hohe Tauern in Salzburg. Besides the results of field work numerous large scaled maps have been exploited. By a great number of cross sections drawn in areas varied as to lithological and tectonical conditions the different slope angles have been compared, the data utilised by way of statistics and represented by many graphs. The present writer had the honor to report on this research at the VII Inqua Congress in 1965 (Tectonic and lithologic control on cirque and trough shaping in Caledonian, Hercynian, and Alpine Mountains of Europe. Abstracts, Internat. Assoc. for Quatern. Research. VII Internat. Congr., General Sessions. Boulder and Denver, Col. U. S.A., 1965. Paper in extenso in print at the Proceedings, Volume 10, VII Inqua Congress, published by the Indiana University Press, 1967). As results of these studies the following facts could be stated.

1. Steep cirque walls occur especially in areas of young tectonic culmination where the valley heads retreated upwards quickly and have been reshaped by local glaciers. Particularly high slope angles are represented where the cirque faces coincide at places with steeply dipping slab-, joint-, or movement-planes of the rock. With tectonically shattered material the slopes are disguised by scree. In fold bends conspicuously semicircular cirque walls develop. In the Bohemian Forest which experienced moderate young uplift and therefore slight glaciation

only few real cirques with walls of a relatively low gradient developed.

The lithologic conditions too control the slope features of the cirques. Especially favorable for the shaping of steep faces is uniform hard rock, e.g. granite, gneiss, basic green rocks or limestone. In soft material the slope angles are much lower.

2. Concerning the slope development in trough-shaped valleys comparative investigations had the following results :

Where by immediate preglacial uplift the last valley floor had been cut by streams as in the Hohe Tauern and marginal areas of the Norwegian mountains, troughs with shoulders originated which developed from the remnants of the dissected earlier valley floor. If a shallow furrow-like cross section upon an old land surface had been redissected shoulderless troughs originated, e.g. in central Jotunheimen. In tectonic depressions being occupied by broad valleys of a low bottom gradient the trough features are not well developed because the flow speed of the Pleistocene glaciers was too low. With mylonitic zones too no steep trough walls develop. The glaciation of the Bohemian Forest was too insignificant as to produce U-shaped valleys.

In troughs whose walls parallel the strike of steeply tilted joint-, bedding-, or movement-planes, the slope angles are especially high and the sides glacially polished. If steeply dipping, tectonically shattered, foliated rocks cross the course of a valley the glacial polish is insignificant. With a series of flags representing an imbricated structure of high dip and striking across the river the trough shape shows only at bastions which project from the valley sides. Between the bastions caused by the tectonic change of rocks of variable resistance deep gullies can be eroded whose sides may follow joint- or movement-planes. Under such tectonic conditions no uniform smooth trough wall is formed. With flatly bedded rocks of changing resistance rough, stepped valley sides developed.

The lithologic control on the shaping of trough walls has been studied by many cross sections of various areas. The narrowest troughs with steepest faces develop with uniform, hard granite, gneiss, gabbro, limestone, and quartzose rocks. With increasing metamorphosis the resistance of the different rocks is uniformised to a great degree which fact favors the origin of typical troughs. An example provides the old rocks of Jotunheiment. In areas of soft materail nearly always slopes of low gradients occur if young uplift has not rejuvenated fluvial downward erosion as is the case in the Taxenbacher Narrows.

On these problems concerning the development of trough and cirque slopes controlled by lithologic and tectonic conditions further research in other areas of the world would be instructive.

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IV. Fluvial processes

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Debris flows, alluvial fans, and a revitalized catastrophism

by

Chester B. Beaty, Lethbridge, Alberta, Canada

with 2 figures and 7 photos

Zusammenfassung: Die Untersuchung der Formation und Veränderung der Schwemmkegel im westlichen Teil des Großen Beckens ergab, daß die umwälzenden Schuttströme auf normale und zu erwartende geomorphologische Vorgänge in der Gegenwart zurückzuführen sind. In dieser Gegend stelle sich das Sensationelle als das Normale heraus, und es wird hervorgebracht, daß hier eine Rückkehr zur Katastrophentheorie der traditionellen, uniformitäristischen Position kaum schader.

Summary: Study of alluvial fan formation and alteration in the western part of the American Great Basin leads to the conclusion that the cataclysmic debris flow is an ordinary and expectable geomorphic event in the contemporary environment. In this region, the spectacular appears to be the normal, and it is proposed that a return to Catastrophism here does no great damage to the venerable Uniformitarian position.

Résumé: L'étude de la formation et de l'altération du cône d'alluvion dans la partie ouest du Grand Bassin nous permet de conclure que l'écoulement cataclysmique de détritus est un développement géomorphique normal et prévisible dans la situation actuelle. Dans cette région, le spectaculaire semble normal et nous proposons que le retour à la théorie du Cataclysme ne met pas réellement en danger la traditionelle position uniformiste.

Introduction

In recent decades, perhaps the most elegant enunciation and defense of the principle of Uniformitarianism has been that formulated by M. Gordon Wolman and the late John P. Miller in their classic paper, "Magnitude and Frequency of Forces in Geomorphic Processes" (1960). With only a limited number of disclaimers, they concluded that in most geomorphologic environments it is

the relatively frequent event of moderate intensity that is responsible for by far the greater share of geomorphic work accomplished and for creation of most of the discrete forms at the earth's surface.

It is the thesis of the present report that in at least one specific geographical locale, the Great Basin of the western United States, the tenets of Uniformitarianism can — and must — be modified, possibly abandoned, and that a modicum of Catastrophism is acceptable and necessary in coming to an understanding of the origin of a significant element of the regional landscape, namely, the alluvial fan.

The Area of Study

Evidence to sustain the postulated thesis comes from the White Mountains of California and Nevada, located in the westernmost part of the American Great Basin (fig. 1). Situated east of Owens Valley, California, in the rain shadow of the southern Sierra Nevada mountains, the range is structurally a large, tilted fault block, or horst (PAKISER, KANE & JACKSON 1964; WAHRHAFTIG & BIRMAN 1965), with a comparatively gentle eastern flank and a much more precipitous western slope. The crest of the White Mountains reaches elevations of 3,650–4,275 m; adjacent valley floors stand 1,200–1,800 m above mean sea level. Relief is thus great in horizontal distances of no more than 1.5–2.0 km, measuring 1,800–2,400 m along much of the western front of the range. Stream gradients, accordingly, tend to be excessively steep, attaining values of greater than 300 m/km in several of the west-side drainage systems.

Mean annual precipitation is relatively low in the White Mountains, even along the crest, averaging about 490 mm at an elevation of 3,800 m (PACE, KITPERT & NISSEN 1968) and dropping to 150 mm or less in the surrounding lowlands. Most precipitation falls as snow during the winter months and is of cyclonic origin, but the morphologically most important moisture supply comes in the form of summer thunderstorms.

Alluvial fans are prominent landforms in the valleys on both sides of the White Mountains. Those along the eastern flank are broad and of low inclination, while the physiographically younger fans in northern Owens Valley on the western side of the range are much steeper and of smaller radius. Mode of formation of the White Mountain alluvial fans has been discussed elsewhere by the author (BEATY 1963, 1970), and it has been concluded that they have been constructed primarily by deposition of successive, overlapping debris flows[1], with only limited amounts of material — perhaps no more than 10–15 percent by volume — added by so-called "normal" stream processes.

1. In this paper the term "debris flow" refers to a relatively rapidly moving mixture of detritus and water in which the water content is 20–60 % by weight or volume. The typical debris flow develops in a stream course or channel as a result of high water, and in the American Great Basin is usually produced by heavy thunderstorm rain. Such flows are considered to be a manifestation of running water as a geomorphic agent rather than a form of mass movement. They occur in stream courses, whereas mass movements may take place on any slope and do not require a definite channel (BEATY 1961, p. 1019).

Photo 1. Low-altitude aerial view of the 1955 debris flow on the Sparkplug Canyon alluvial fan.

Fig. 1. Location of the White Mountains, western American Great Basin.

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Photo 2

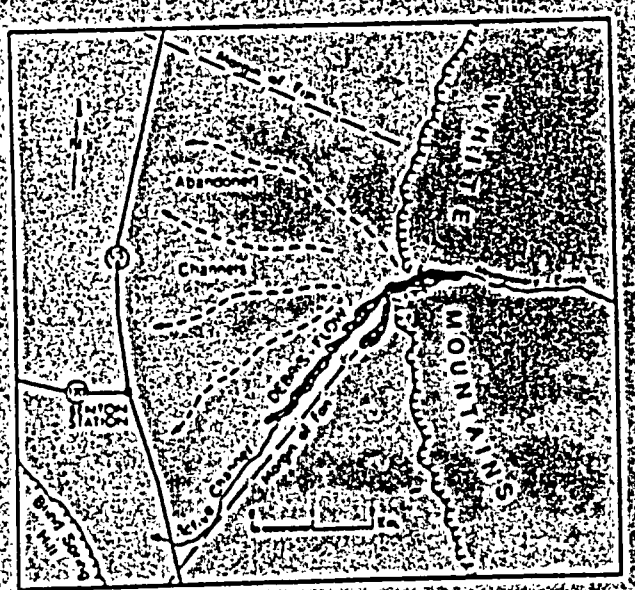

Fig. 2.—Montgomery Creek alluvial fan, northwestern White Mountains, showing location of the debris flow of July 30, 1965. Base: U.S. Geological Survey 15-minute Benton, Nev.—Calif. topographic quadrangle.

Photo 1. View of the greatly enlarged active channel of Montgomery Creek near the mouth of the lower canyon. The figure on the floor of the channel provides scale and suggests the remarkable size of the fresh cut.

Photo 2. Quartzite boulder, transported from a site in the lower canyon to the alluvial fan by the 1938 debris flow in the Sparkplug Canyon drainage system.

Photo 4 A & B.—Before and after views looking downstream in the Montgomery Creek canyon from about 1.5 km above its mouth. 4 A—1956; 4 B—1966.

Photo 5 A

Photo 5 B

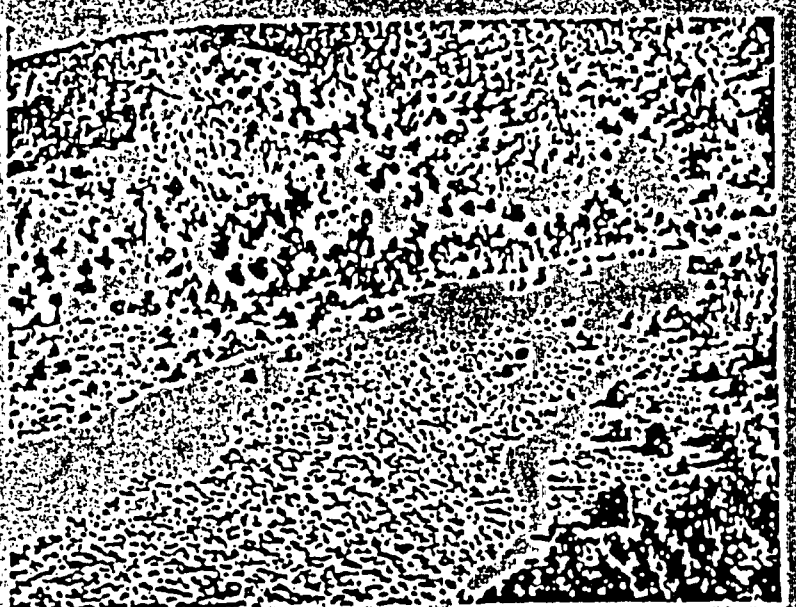

Photo 5 A & B.—Before and after views of the floor of the Montgomery Creek canyon about 0.3 km above the canyon mouth. 5 A—1956; 5 B—1966. Spreading of the debris flow of 1965 and branching off of a subsidiary lobe are visible near the center of the righthand margin of 5 B.

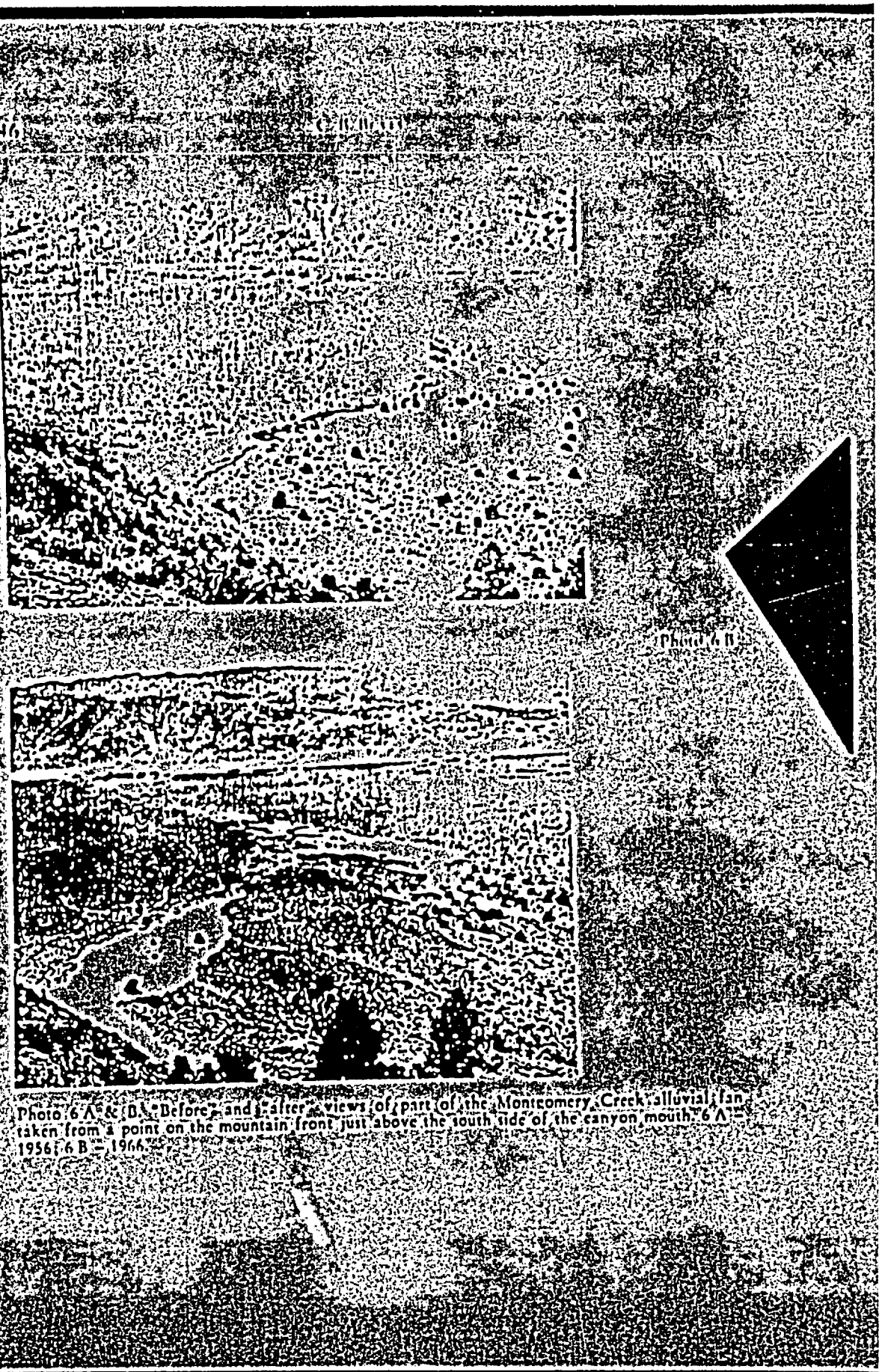

Photo 6 A & B. Before and after views of part of the Montgomery Creek alluvial fan taken from a point on the mountain front just above the south side of the canyon mouth. 6 A - 1956; 6 B - 1966.

Photo [illegible] Low-altitude aerial view of the active channel of Montgomery Creek at the canyon mouth [illegible] Greatest enlargement of the channel occurred in this segment of the stream course during the debris flow and flood of 1965. The scattered pinyon pines (*Pinus monophylla*) to the left of the channel are [illegible] m high.

The Desert Range Debris Flow

It is here contended that the debris flow, undeniably representing a spectacular geomorphic process, is an ordinary and expectable physiographic event in the contemporary regional environment of the White Mountains, and that in this particular area – and by analogy, in other mountainous deserts of the world – a return to the principle of Catastrophism as a working hypothesis is not only suggested, but is a virtual necessity.

Two large debris flows occurred on the western side of the White Mountains during the decade 1957–1966 (BEATY, 1968). One was evidently produced by snowmelt runoff, while the other was generated by a summertime cloudburst. The flow triggered by snowmelt took place in the Sparkplug Canyon drainage system probably in late May, 1958. Its morphology is representative of most White Mountain debris flows: it consists of an elongated, tongue-shaped mass of fresh rubble, ranging in thickness from a few centimeters to 2–3 m, spilling from the active channel on the fan near the apex and splitting into several narrow lobes below the point at which channel overflow happened (photo 1). This flow overlaps part of an older debris flow which is believed to have occurred in the late 1940s, and in places the margins of the two are essentially parallel. Materials moved in the flow of 1958 vary in size from silt and sand to boulders as much as 2.0–3.5 m in diameter. One 3.2 metre quartzite boulder, photographed by the author on the floor of the lower canyon within the mountains in 1956, was transported approximately 2 km to a new position in the active channel on the upper part of the alluvial fan (photo 2).

The other major debris flow of the decade, which developed as a result of heavy thunderstorm rain, surged out of the catchment basin of Montgomery Creek on the northwestern flank of the White Mountains on the night of July 30, 1965 (fig. 2). There were no eyewitnesses to this event, but for more than an hour people in the nearby settlement of Benton Station (see fig. 2) heard the loud, rumbling noises that have frequently been reported as emanating from debris flows in the American Great Basin. As has commonly happened during flooding in other parts of the region, the mass of fluid debris in Montgomery Creek tended generally to follow the active channel in the canyon and on the alluvial fan. However, at one point within the lower canyon, temporary damming of the channel brought about a spreading of the rubble and the branching off of a subsidiary lobe of debris (see photo 5 B). At the mouth of the canyon and on the fan apex, the active channel was deepened and widened almost beyond previous recognition (photo 3). Selected pairs of "before" and "after" photographs, taken 10 years apart, give some indication of morphologic changes produced in lower Montgomery Creek canyon and on the alluvial fan (photos 4, 5, 6).

There is evidence suggesting that a high-water flood, heavily charged with sand and pebbles, closely followed deposition of the main mass of rubble. Similar flooding after the occurrence of large debris flows has often been reported in the American Great Basin. At several places in the lower canyon of Montgomery Creek, a thin layer of finer material overlies coarser debris near the edge and on the walls of the active channel, providing clear evidence that the finer debris

was deposited *after* the coarser material had come to rest. Although unequivocal proof is not available, it is believed that much of the deepening and widening of the channel at the mouth of the canyon and on the upper part of the alluvial fan (photo 7) was accomplished by the high-water-flood, which was also responsible for deposition of the finer debris on top of the coarser (BEATY 1968, pp. 43–45).

In any event, whereas in 1957 the channel in the lower canyon and on the upper fan was 0.7–1.3 m deep and 2.7–3.2 m wide, it is now nearly 12 m deep in places and as much as 10–13 m across (photos 3, 7). It is worth emphasizing that this impressive channel enlargement took place in less than two hours, possibly in no more than one hour, judging from the comments of local residents who admittedly *heard*, rather than saw, the debris flow and flood. It is also of interest to note that the hand of man played no role in bringing about this episode of cutting; the Montgomery Creek drainage system has never been grazed, logged, or otherwise disturbed in any significant way by human activity.

Discussion and conclusion

It could be argued, or supposed, that the two debris flows of the 1957–1966 decade were unusual, or unexpected, or of an intensity rarely experienced today in the White Mountains, but such appears not to be the case. At least seven flows of comparable magnitude have debouched from canyons on the western flank of the range within the last 35 years (KESSELI & BEATY 1959; BEATY 1968). Study of newspaper files and discussions with long-time residents of the area indicate that two to three times as many have taken place during the historical period, which reaches back to the 1860s in this region. A considerably greater frequency of occurrence during the historical period has been reported from the state of Utah in the eastern Great Basin (WOOLLEY 1946, pp. 84–120). Unfortunately, in most instances precipitation intensities needed to generate debris-flow-producing floods can only be estimated. Measured and accidental catches amounting to 50–100 mm/hr have been recorded or reported in the western American Great Basin during the period of interest (KESSELI & BEATY 1959, pp. 18–24), and in at least a few cases it has been possible to associate precipitation values from a particular thunderstorm or heavy frontal rain with a given debris flow or high-water flood (BEATY 1968, pp. 53–54, 73–74). On the basis of a regrettably fragmentary record it seems probable that an intensity approaching or exceeding 50–70 mm/hr is required before debris flowage will occur (BEATY 1968, p. 87). Intensities of this value or higher, as noted, are known to have been achieved in the region during the past century, and therefore cannot be considered "unusual". Here, then, the cataclysmic debris flow is *not* a thing of the past, a relic of the Pleistocene. It is, and apparently for a long time has been, the major erosional, transportational, and depositional agent in this particular environment.

In spite of ideas to the contrary, the effects of so-called "normal" stream activity in the western Great Basin appear to be minor, at best. Specifically, in the White Mountains, and probably in comparable desert ranges elsewhere, it

appears to be the occasional debris flow associated with thunderstorm rain that flushes most alluvial and colluvial deposits completely out of the highlands, moving clastic materials much too large to be transported at times of "normal" discharge (which in many White Mountain drainage systems is *zero* discharge). Dramatic channel enlargement in a remarkably short period of time has often been a concomitant phenomenon. More infrequently, copious snowmelt runoff has performed essentially the same morphological chores. Most of the detritus thus removed from trunk canyon floors within the mountains is deposited on subjacent alluvial fan surfaces, in the form of lobes or tongues of coarse debris such as those illustrated above. The available evidence strongly suggests that the fans consist in large part of accumulations of superposed debris-flow deposits, modified only slightly by "normal" erosional and depositional processes. Most gradation in the region, in short, is spectacular, cataclysmic, catastrophic! And during prolonged intervals between the sudden, morphologically dramatic events, the frequency of which may be no more than two or three per 1,000 years in a given stream system (or, on occasion, may be twice within a couple of decades), physiographic change on the fans and in the mountains appears to have been (and to be today) only minimal.

It may well be that what is most needed in this context is a careful re-examination of the meaning and use of certain words. After all, if a cataclysmic event is "normal" in a particular environmental situation, as the desert range debris flow is here considered to be, are we really justified in speaking and writing of contrasting "Catastrophic" or "Uniformitarian" processes? In the White Mountains and probably elsewhere in the world as well, the catastrophic *is* the normal, although on a very large scale over the passage of tens of thousands of years a certain massive Uniformitarianism may be discernible. But for short time spans, on the smaller scale of an individual drainage system within the range, Catastrophism certainly prevails.

As a functional generalization and as a guide to study of processes at the earth's surface, the principle of Uniformitarianism undoubtedly has lasting value. That value will hardly be impaired by the introduction of a judicious Catastrophism from time to time and place to place. The American Great Basin, it is firmly believed, is one such place, and the time is now.

Acknowledgements

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