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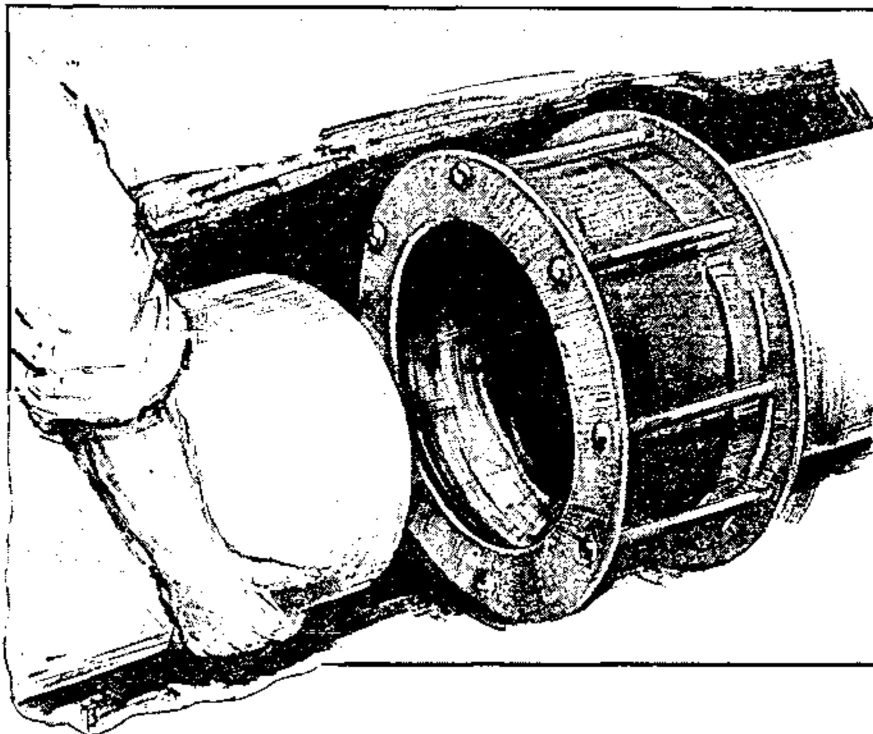

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JUNE, 1966

Thai–New Zealand Feeder Road Project

By LIEUT-COLONEL K. C. FENTON, RNZE, BE (Civil), MNZIE[1]

PART ONE—INTRODUCTION

Summary. This paper outlines the considerations which led to the inception of the Thai–New Zealand Colombo Plan feeder road project in North-East Thailand, describes the terrain through which the road will pass and summarizes engineering aspects of the geology, soils, and rainfall of the region. The project is a joint venture between the Thai authorities, the New Zealand Department of External Affairs (which is responsible for the expenditure of Colombo Plan funds) and the New Zealand Army. Project planning and organization is described and information is given on initial design and construction aspects. Finally, the advantages which are expected to derive from the project are summarized.

The paper is divided into five parts:—

Part I	Introduction
Part II	The Korat Plateau
Part III	Project Planning and Organization
Part IV	Design and Construction Aspects
Part V	Conclusion

General. Thailand's first National Economic Development Plan was prepared to cover the period 1961–6. Its primary objective is to raise the standard of living of the people of Thailand, and to find solutions to basic economic problems such as the rapid rate of population growth and the low agricultural and industrial productivity. As an example, if the current rate of population growth of 3 per cent per annum continues, the present population of 30 million will have reached a figure of 50 million by 1982.

The north-eastern region of Thailand comprises an area of about 170,000 sq kilometres with a population of 8.8 million in fifteen provinces. It is of particular economic and political significance as it is underdeveloped, remote from central government and generally lacks roads and other facilities for social and economic progress. The Royal Thai Government has been implementing measures to promote the social and economic development of the north-east within the framework of its National Economic Development Plan. The region is strategically important, possessing long frontiers with adjacent states.

Special attention is being given to roading development, either in the form of main highways or "feeder" roads in the north-east. Until the construction of the Friendship Highway from Bangkok to Korat (Nakhon Ratchasima) and its extension, as the North East Highway, to Nong Khai on the Mekong River, access to this region has been difficult. In addition a subversive Communist propaganda and insurgency campaign is now being directed towards the people of the north-east. Consequently priority for construction must be given for internal security as well as for economic and social reasons. Lack of communications tends to weaken Government control and countermeasures against subversion. The position of the North East Highway in relation to the region it serves is shown in Figs 1 and 2.

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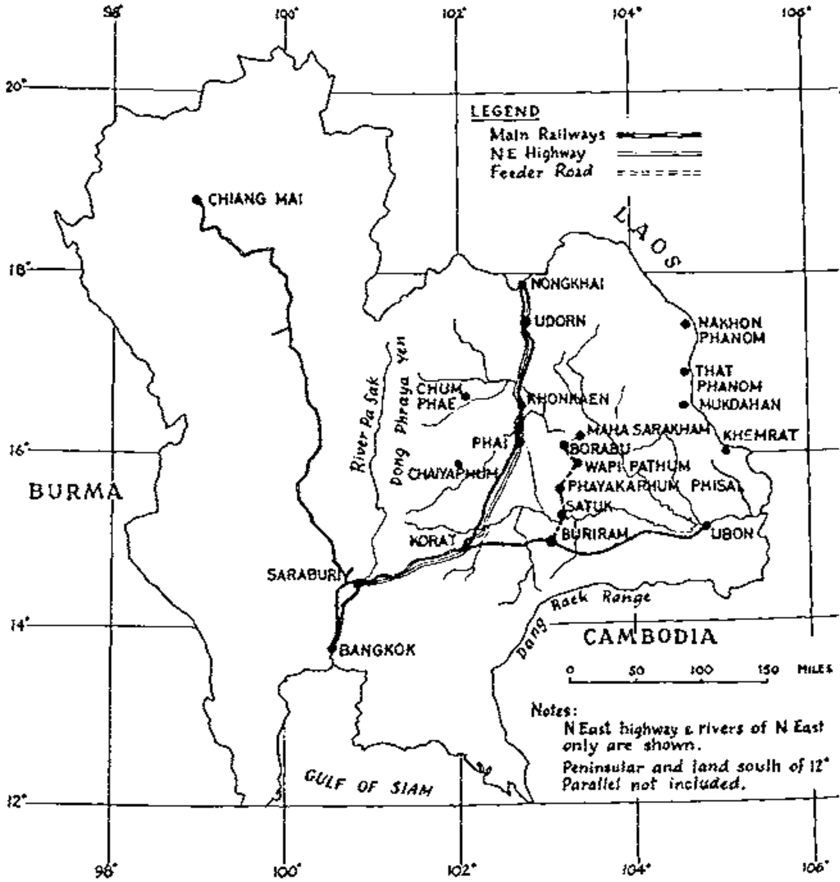


Fig. 1. Kingdom of Thailand, showing location of Thai–NZ Feeder Road Project.

Development Plan for North-East Thailand. The Royal Thai Government plans to create three to four urban centres in this region. In each of these centres Government services will be concentrated and public utilities and other necessary facilities provided. Besides agricultural improvements, it is intended to promote industrial investment. As these urban centres expand, area development will follow and outlying areas now remote and inaccessible will be linked by roads. Only a few waterways in the region can be used for transportation as in the rainy season many rivers have rapid flow, while in the summer, or dry season, they dry up. As railway lines provide connexions for only eight provinces, highways and feeder roads assume great importance in economic planning.

Khon Kaen has been chosen as the first "agri-metro centre". This city, located on the North East Highway—about 390 miles from Bangkok, is now the scene of major development. A hydro-electric project at near-by Nam Pong has been completed while the University of the north-east has been established in Khon Kaen itself, initially providing faculties of agriculture and engineering. This University has been established with Colombo assistance from Canada and New Zealand.

Also located at Khon Kaen is the headquarters of the Thai–Australian road project. This project, undertaken by the Thai and Australian Governments under a Colombo Plan agreement, trains Thai personnel in various aspects of highway construction and in the use and maintenance of earthmoving equipment. The training is carried out on actual construction sites, the dual aim being to construct modern all-weather feeder roads and at the same time increase the number of Thais trained to operate and repair earthmoving equipment. By 1966, it is planned that 125 miles of road will be complete and thirty engineers, 175 plant operators and sixty fitters will have received instruction on the various aspects of highway construction. Under the initial agreement, the project was planned to cost 130 million baht (say £NZ 2.2 million) the Australian contribution being 69 million baht or 53 per cent of the total.

The Thai–New Zealand Project. Following discussions between the New Zealand Government and the Royal Thai Government early in 1965, the New Zealand Government approved in principle the offer of assistance with feeder road construction in the north-east. The New Zealand Government proposed that up to fifteen New Zealand Army engineers would be provided for the project and that roadmaking machinery and other equipment to a value of £NZ 240,000 would be supplied under the Colombo Plan. An additional £60,000 of Colombo Plan funds would be spent in maintaining the Army engineering team in Thailand. Apart from the £300,000 of Colombo Plan funds, it was decided that salaries of personnel and the cost of RNZAF movement to and from New Zealand and Thailand would be met from the defence vote. In March 1965 the writer visited Thailand to reconnoitre the region and the proposed route of the feeder road with civil engineers from the Thai Departments of Technical and Economic Co-operation and Highways. After discussions in the north-east, at Bangkok and in Wellington, New Zealand, a "Memorandum of Understanding" was effected between the Royal Thai Government and the New Zealand Government. This memorandum concerns the contributions and responsibilities of the respective governments with regard to the construction of a feeder road to run from Borabu towards Buriram over a route to be surveyed jointly and agreed between the Thai and New Zealand authorities.

Subsequently in March 1966, New Zealand increased its contribution of "Colombo Plan" funds from £300,000 over a period of three years to £450,000 over a period of five years. It is now recognized that the project would take five years to complete and it is estimated that the road and drainage structures would cost in total about £2 million. Thailand would meet all costs in excess of New Zealand's £450,000 contribution.

Briefly, the New Zealand Government is providing supervisory and instructional personnel (fifteen), and their salaries and expenses, and a range of earthmoving and road construction equipment, workshops equipment, a soil mechanics laboratory, survey equipment, a prefabricated steel building for use at the roadhead as an advanced workshop and a range of spare parts to cover at least the first year's usage. The Royal Thai Government is providing a permanent depot at Maha Sarakham, including offices, workshop, stores, married quarters for New Zealand and Thai personnel, and single men's accommodation. At Borabu, where road construction commences, a temporary field camp as well is being provided by the Thai Government. The Thais are also providing all land for road reservation, construction materials, culverts and bridges, some motor vehicles, and all items including personnel, not listed as a New Zealand contribution.

The Thai–New Zealand project differs from the Thai–Australian project in two main respects. Firstly, the New Zealand percentage capital equipment contribution is smaller, being earthmoving equipment purchased mainly in the United States of America following competitive tendering arranged by the Stores Manager, Ministry of Works. The initial Australian contribution of equipment included, however, many items made in Australia. Secondly, the New Zealand commitment is to construct a single feeder road while the initial Australian commitment has been to construct several roads generally "radial" about Khon Kaen, eg Khon Kaen–Yang Talat. The Thai–New Zealand road, in the words of the agreement, is

". . . to run from Borabu towards Buriram over a route to be surveyed jointly and agreed between the Thai and New Zealand authorities."

From a study of Figs 1 and 2, it will be seen that the Thai–New Zealand base depot is located at Maha Sarakham, a provincial capital 400 miles from Bangkok and about 14 miles from Borabu where the road commences. The proposed alignment ends at Buriram, about 106 miles to the south. This imposes problems of organization and control which are in some respects quite different from those encountered in the Thai–Australian project.

Part Two—The Korat Plateau

Landform and Drainage. The three major drainage areas of Thailand are the central Thai mainland draining south into the Gulf of Siam, peninsular Thailand between Burma and Malaya, and the north-east/eastern plateau region. This eastern drainage area is known variously as the Korat Plateau or Korat Basin. It is bounded in the north and partly in the east by the Mekong River, in the south-east and south by the Phanom Dang Raek (Dangrek Chain) and in the west by a series of ridges which divide it from the Central Plain of Thailand and the Mae Nam Pa Sak Valley. The Phanom Dang Raek peaks are generally about 1,500 ft, while the fairly dissected ridges to the west are about 1,000–2,000 ft elevation.

Although known as the Korat Plateau, the elevation, from 325–650 ft, is only slightly above that of the plain. It extends more than 200 miles east-west and 280 miles north-south and has developed on thick bedded horizontal sandstones. The Korat tilts slightly downward towards the east, drainage being through broad incised valleys, notably those of the Chi and Mun Rivers. The route of the Thai–New Zealand feeder road lies completely on the plateau and crosses the Mun River near Satuk. This river which flows eastward across the eastern drainage area for about 300 miles, averages 1 ft per mile gradient. During the dry season the Mun River varies between 2–6 ft in depth, while in the wet it averages about 15 ft. Its width varies from 36 to 75 ft along its upper course, to from 675 to 1,200 ft at Ubon, a city lying about 80 miles from the Mun's confluence with the Mekong. Figure 2 defines the plateau and its principal towns and routes.

It has been said that the Korat soils have suffered, not from too much erosion but from too little. While the Korat has a tropical monsoonal climate with 80 per cent of the rainfall between May and October, the moderate relief, gentle slopes, and porous bedrock have combined to produce a situation where weathered surface materials are not removed rapidly enough to expose more virile underlying horizons. Such conditions contribute to the development of insoluble laterite layers. While there are extensive areas of poor sandy loams, the river flood plains, such as the Mun Plain, have more fertile alluvial soils and it is here that extensive agriculture has developed.

Rainfall. The total rainfall on the plateau area through which the road will pass is not excessive if measured against the rest of Thailand. For comparison the annual rainfall at Maha Sarakham is about 43 in while at Nakhom Phanon, on the Mekong, it is about 85 in. At Table 1 is given monthly rainfall for two localities, Maha Sarakham and Buriram, one at each end of the route. On the river flood plains, extensive inundations occur in the wet season, but along other parts of the road alignment, there is reason to believe that it will be practicable to work throughout the year. Nevertheless the intensity of precipitation which is as much as 3.5 in per hr, together with the large percentage of the yearly rainfall occurring within a few months, produces real problems for the road constructor. Figure 8 shows intensity–duration relationships for ten and twenty year frequencies on the Central Plain. No intensity–duration records are available for the north-east region, but rainfall intensities are of the same order of magnitude and these curves are being used in the design of Thai–New Zealand feeder road drainage structures.

Geology. The Korat "Plateau" or basin, occupies a saucer-shaped depression formed in the underlying bedrock, which is predominantly sandstone or shale with a few small flows of basalt overlying sandstone in the south (eg near Buriram). More complex formations underlie the sandstone and shale, and in the west and south consist of shale, slate, conglomerate, limestone, and granite. However, in the area of the Thai–New Zealand feeder road, bedrock is mainly sandstone. Figure 2 has been produced in part from a geologic map originally prepared by N. Challchan and D. Bunnag.[1] (Fig. 1).) The cross-section, Fig. 3 shows the general relationship of rocks and soil along a south-west-north-east line.

It will be seen that layered rocks of various types comprise the plateau, mainly being fine to medium grained sandstone d·composed to depths of up to 50 ft, the surface being commonly sandy. Thus, apart from Buriram in the south, where basalt occurs but is not quarried to any degree, nowhere in the area is there any well-indurated rock such as—the New Zealand basement rock—greywacke, suitable for road construction. Alluvial and terrace gravels are not plentiful, and it has been a local practice to bring in sealing chips by road and rail from Sara Buri, about 330 miles to the south of Maha Sarakham.

Soils. Grey and brown silty and sandy loam ranging from 2 to 5 ft overlies much of the plateau. This is underlain by mottled red and brown clay and may contain laterite in its soft form as well as hard concretionary laterite. This grey and brown soil is the one that mainly lies on the road alignment, although adjacent to the Mae Nam Mun, alluvial soils of recent origin are found. These consist of sandy loam on levee banks and clay and silty clays in the flood plains behind the banks.

No discussion of the soil structure of the Korat would be complete without reference to laterite, the idealized sequence of which is given in Fig. 4A. (After Nixon and Skipp.[2]) The vesicular or concretionary laterite, or clay

[1] Challchan, N., and Bunnag, D., Geologic Map of the Korat Plateau.

[2] Nixon, I. A., AMICE, and Skipp, B. O., PhD, FGS: "Airfield Construction on Overseas Soils Part 5: Laterite." Institution of Civil Engineers Paper No 6258.

gravel, upon exposure to the air and prolonged drying, changes from a soft material to a hard cemented mass. Figure 4 B typifies its occurrence on the Korat.

It is well known that laterite tends to occur in tropical areas where the landform is level or gently sloping and not subject to much mechanical erosion. There has been no generally agreed definition or classification of what laterite comprises, but there is general agreement that the weathering producing it is primarily chemical and subaerial and is found in regions of alternating wet and dry seasons. It has an excess of alumina and iron oxide and behaves on excavation as a soft granular material with a clay binder. Nixon and Skipp[2] define the term laterite as applying to "ferruginous and aluminiferous materials having a vesicular concretionary appearance, which cap a soil profile of either *in situ* development over parent rock or similar material found in detrital deposits, which can be recognized as of local origin, that origin being clearly associated with a laterite profile".

Nevertheless the occurrence of surface deposits of laterites along the alignment of the feeder road is very limited and an extensive search programme has been instituted to locate suitable types and quantities of material for road building. It would appear that the degree of soil laterization is not as great between Borabu and Buriram as elsewhere on the Korat Plateau and for this reason consideration is being given to the advantages of soil cement stabilization. Whatever design is adopted for the road pavement, it is clear that large-scale blending of the proposed materials will be necessary. At the time of writing, only one source of laterite, about 30,000 cu yds or more in extent, had been discovered at a distance of 19 miles from the road alignment.

Agriculture and Forestry. The visitor to the Korat Plateau soon appreciates the importance of rice growing to the people of the region. The landscape is broken by the irregular pattern of low earth walls or bunds, within which subsistence farmers contain the water necessary for the growing of the one rice crop a year. At the time of writing, engine-driven pumps are not widely available and a common domestic scene is that of the wife, husband and perhaps other members of the family engaged in moving water from a lower to a higher padi field. A light tripod, from which is suspended a water scoop with a wooden handle, is erected near the low earth wall separating the fields. The water is scooped from one to another with a semi-rotary motion until the upper padi is adequately watered. Figure 5 shows a typical plateau landscape with the irregular subdivision into rice padi.

However, quite apart from rice growing, the north-east yields many other crops such as maize, Kenaf, beans, sugar cane, castor beans, cotton, tobacco, kapok, and it is the intention to encourage the local people to grow field crops in place of or in rotation with rice. Also fruit, such as bananas, paw paw, mangostin are widely grown and in season provide a cheap source of food as well as adding variety to the diet.

Forestry has an important place in the economy of the Korat. The merchantable teak forests lie outside the north-east region, but three deciduous dipterocarps have commercial significance and grow to a good height. These are Yang, Takien, and Tengrung. Yang is a moderately hard and heavy timber (44–49 lb per cu ft at 15 per cent moisture content) somewhat similar to the Malayan dipterocarp Keruing. It is moderately resistant to decay. Takien is strong and elastic, hard and heavy (47 lb per cu ft at 15 per cent moisture content) being very durable and resistant to termites.

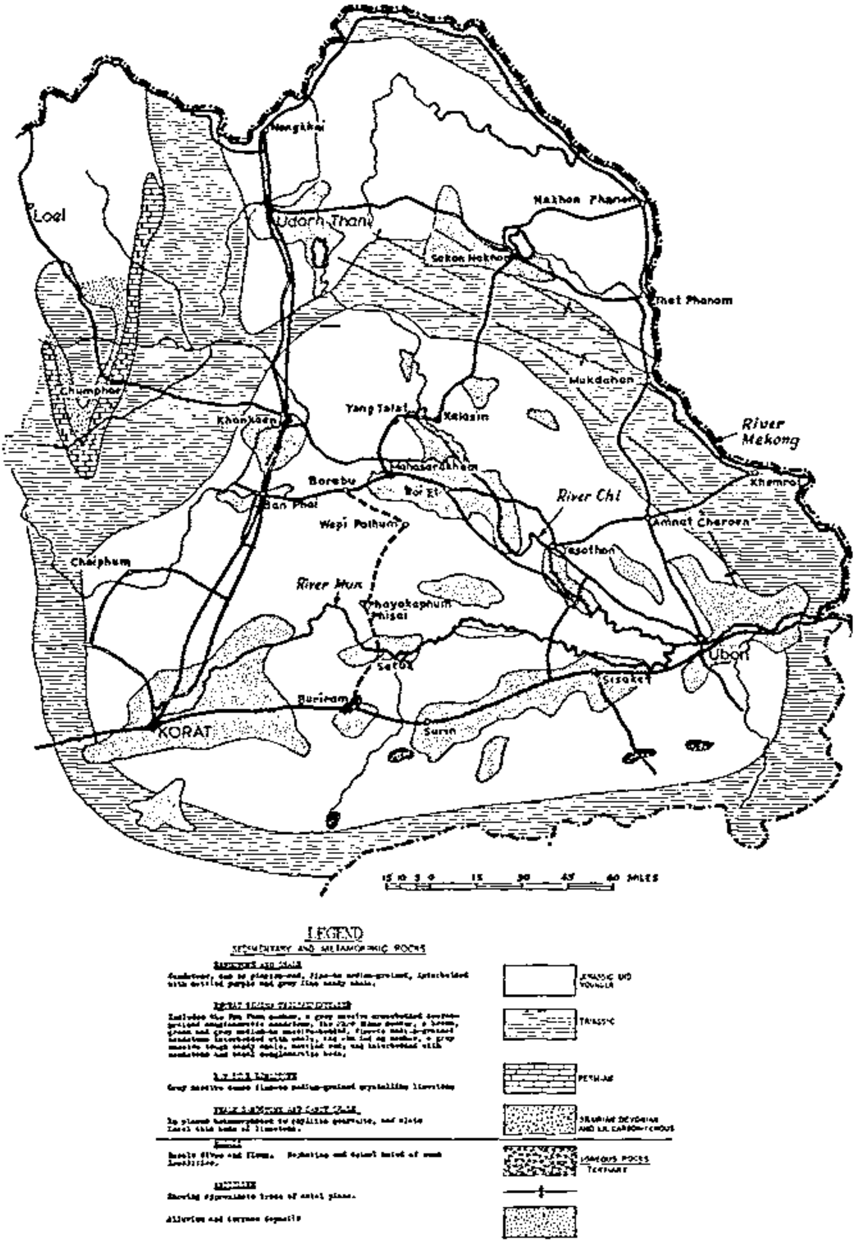


Fig. 2. Geologic Map of the Korat Plateau.

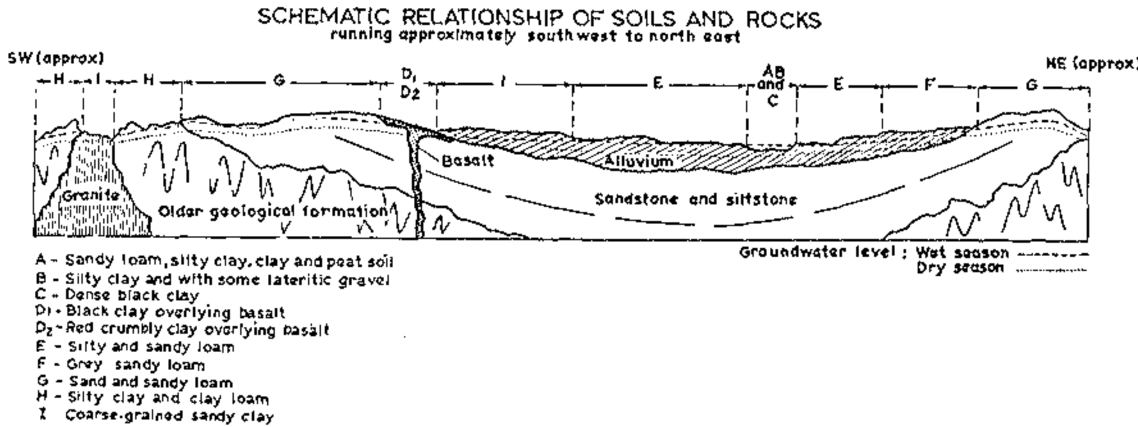


Fig. 3. Cross-section of Korat Plateau showing a generalized relationship of rocks and soils.

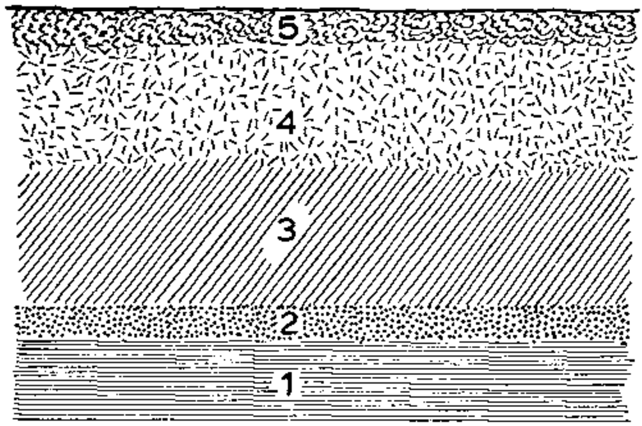
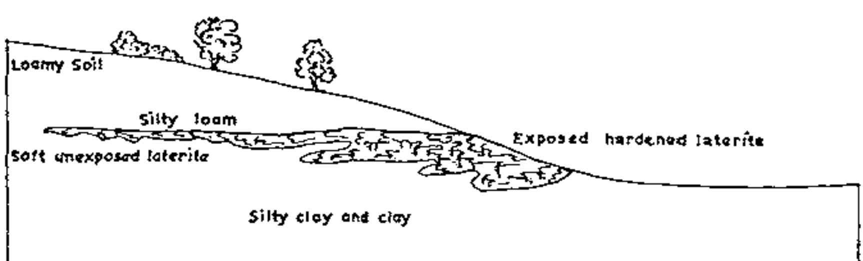


Fig.4 A

IDEALISED SEQUENCE OF LATERITE

NOTATION

SERIAL	SEQUENCE	ENGINEERING DESCRIPTION
1	Parent Rock	Bedrock
2	Decomposed rock zone	
3	Clayey lithomarge with kaolinites mottled at top, becoming straw yellow with depth; perhaps containing residual quartz.	Clay or Silt often sandy
4	Vesicular concretionary laterite	Clay-gravel
5	Ironstone caprock	Rock



KORAT LATERITIC SOIL PROFILE

Fig.4B

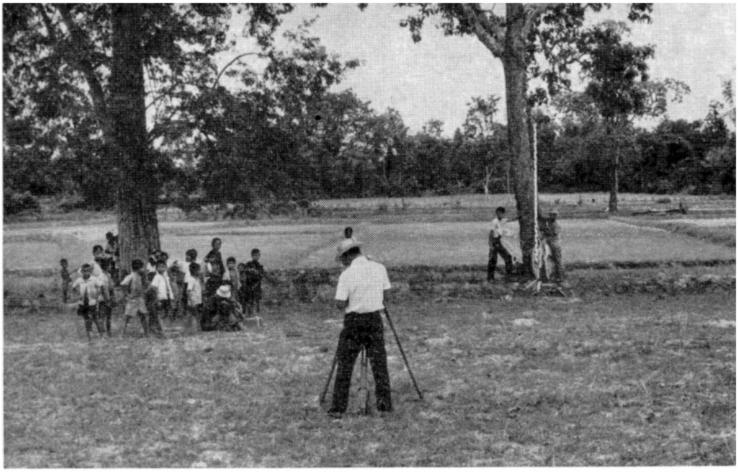


Fig. 5. Typical Korat Landscape near feeder road.

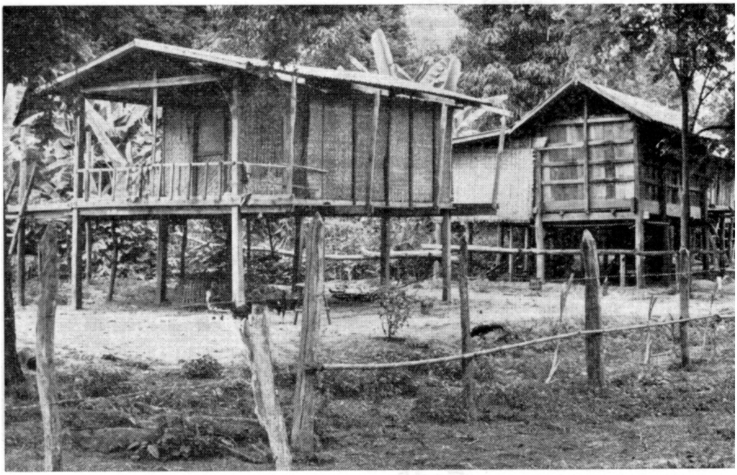


Fig. 6. Typical Rural Housing—Korat Plateau.

Thai-NZ feeder Road Project 5,6

The line of the feeder road passes through forests of light to medium density, comprising not only these broad leafed dipterocarps, but also other species, and besides providing a farm to market road for the crops mentioned above, it will enable timber to be transported to mill and railhead more readily than at present. The greater part of the area contiguous to the line of the road is criss-crossed with foot trails through the forest and across open plain, and dotted along these trails are small villages. Timber is an important material for the Korat villager, as his house, plough and many other necessaries of life are made from it. Figure 6 shows typical rural homes in a hamlet near the start of the feeder road. Corrugated iron used as in this case on the roof is of light gauge transported along the forest trails as a roll on the shoulder of the person carrying it.

Figure 5 shows a group of interested villagers near the road alignment, taken during survey operations in June 1965. The group of young children typifies the large juvenile population. It has been assessed that by 1982, 46 per cent of the population of Thailand will be under 15. On the Korat, one cannot fail to be impressed by the large numbers of young children who seemingly appear from nowhere in even the most remote areas, when a European in a "Landrover" arrives on the scene. This high population of children is a tribute to the effectiveness of the recent health promotion measures, which have been so successful in the control of malaria and other diseases. The Thai National Malaria Eradication Project has been aided by the Agency for International Development, United States Operational Mission, and the World Health Organization.

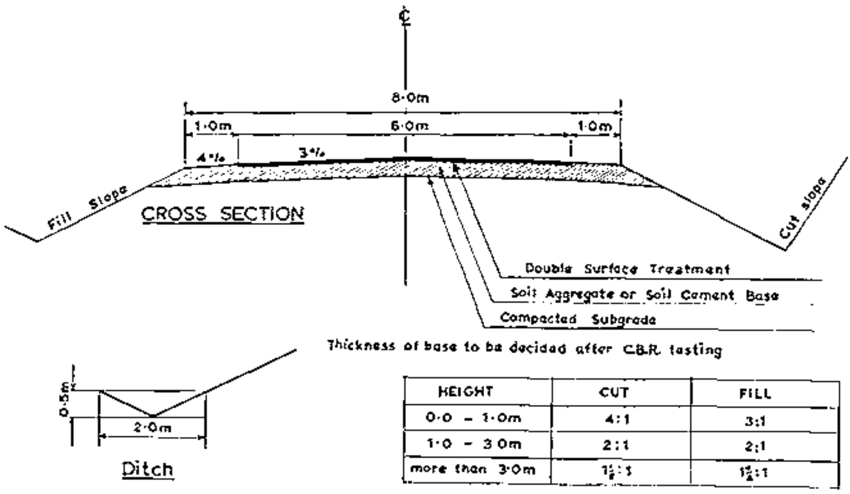
Part Three—Project Planning and Organization

It is a fairly complex task to mount an operation of this nature with personnel coming from both Thailand and New Zealand and equipment mainly from USA. A summary of the main events in which RNZE were involved is tabulated in Table 2. From this table it will be seen that concurrent events were taking place in Thailand and in New Zealand. The two critical timings were the date for completion of the New Zealand married quarters and the date by which sufficient plant to enable a start to be made would have been delivered to Maha Sarakham. Originally it was hoped that some road construction would commence in November 1965, so that advantage could be taken of the whole dry season. However, cumulative delays have resulted in the starting date being put back to late February 1966, by which time most of the plant will be available for work and the Maha Sarakham married quarters complete.

The progress made in mounting the operation is very encouraging as the terms of the understanding have been methodically implemented by representatives of both nations. Much goodwill has been engendered at working level where for a substantial period all engineer liaison in Thailand was undertaken by a young graduate RNZE officer. This involved his living and working with the Korat villagers along the survey line—a lone European on that part of the plateau.

Personnel

Definition of the Role of New Zealand Personnel. The New Zealand Government agreed to provide fifteen instructional and supervisory personnel to further the dual aim of the project—road construction and technical training



HEIGHT	CUT	FILL
0·0 – 1·0m	4:1	3:1
1·0 – 3·0m	2:1	2:1
more than 3·0m	1½:1	1½:1

Fig. 7. Typical Road Cross-Section.

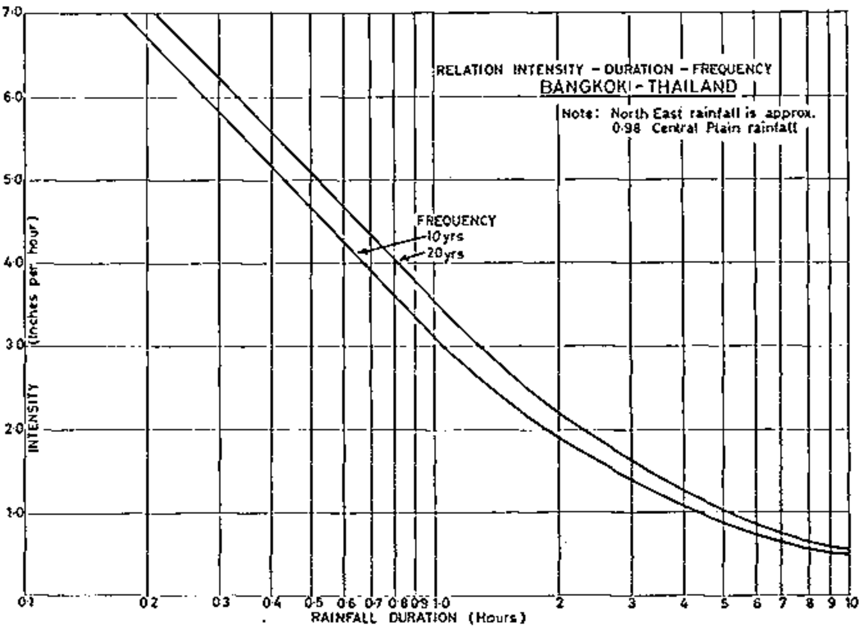


Fig. 8. Rainfall–Intensity–Duration–Frequency Relationship.

of Thai personnel. In determining the optimum number to be provided consideration was given to the envisaged method of project management, to the financial commitment of the New Zealand Government and to the period each member of the team would remain in Thailand. In view of the considerable experience the Corps of Royal New Zealand Engineers had recently obtained in Thailand and because of the remote location of the project, it was decided that the military engineer personnel would form the New Zealand team.

It is planned that the project be managed on a joint basis with RNZE providing "counterpart" personnel for each major appointment. The Thai project manager's New Zealand counterpart is the Officer Commanding 5 Specialist Team (Road Construction) RNZE who is also known as the "counterpart" project manager. Similarly, there are two deputy project managers, one Thai and one New Zealander, and Thai and New Zealand foremen for construction, plant and workshops. Thus the requirement was for two main groups of New Zealand personnel namely:—

(*a*) Officers with military, civil and mechanical engineering qualifications.
(*b*) Construction, plant and workshop foremen.

The administration officer is required for certain project administration and costing duties and also for the local administration of New Zealand personnel. It was necessary to provide for sufficient construction officers to be available for rotation of duties and the establishment of an advanced camp as the roadhead moved farther away from the main base. It is intended that RNZE and RNZEME personnel be fully integrated with Thai personnel within a common project organization and that the maintenance of New Zealand personnel be effected by local purchase of food and other necessaries. Thus the designed establishment of the New Zealand Army team is numerically lean by military standards.

Establishment. The fifteen New Zealand personnel comprise a small unit known as 5 Specialist Team (Road Construction) RNZE with its own establishment and equipment table. The establishment is as follows:—

Commander	Major RNZE	1
Deputy Commander	Major RNZE	1
Administration Officer	Captain RNZE	1
Construction Officers	Captain or Warrant Officer Class I	2
Military Foreman of Plant	Warrant Officer Class I	1
Senior Instructor, Plant Operation	Warrant Officer Class II	1
Instructors, Plant Operation	Staff Sergeant	3
Soils Laboratory Technician	Staff Sergeant	1
Workshops Officer	Captain RNZEME	1
Workshop Foreman	Warrant Officer Class II	1
Instructor, Plant Repair	Staff Sergeant	2
	Total	15

The ranks are the maximum that may be held by each appointee, the rank structure being kept high to enable maximum flexibility in posting suitably qualified personnel.

Personnel Policy. The writer recommended that eight of the fifteen personnel comprising the New Zealand component be married soldiers accompanied by their families for a two-year tour of duty. It was necessary to employ married men as the more senior personnel required for this type of duty are normally married. However, as the regular Corps of Royal New Zealand Engineers is numerically small, married men, if unaccompanied, would spend unduly long periods away from their families, before a relief could be provided, or alternatively be posted for a relatively short period which would be insufficient to maintain continuity in appointments and the fabric of "counterpart" relations. As neither of these latter alternatives were considered acceptable, it was recommended to and accepted by Army HQ and External Affairs Department that married personnel go to Thailand with their wives and families. The housing which the Royal Thai Government provided was recently built to an agreed specification at the Base Depot at Maha Sarakham.

In view of the lack of secondary school facilities, it was decided that married personnel would be selected from the group with children of primary school or pre-school age. The team now in Thailand comprises eight married soldiers, their wives, and twenty children, and seven single soldiers (or married unaccompanied) spending only six to eight months with the project.

In the selection of personnel for the team, in addition to engineering skills, other soldier skills, and civil qualifications of the wives were considered. Thus it was possible to include in the party a Territorial Engineer officer and his wife both with country school teaching experience while two other wives have experience in school teaching. Special attention was given to the need to select personnel who would work harmoniously with their Thai counterparts and who would be genuinely motivated by a desire to contribute to the advancement of the people of the north-east.

Much care has been taken to attain a high standard of married housing. Clearly, in this remote location efficiency will be even more dependent on the morale and health factors, and good housing will help greatly in this direction. Each house comprises three bedrooms upstairs, a lounge, dining-room, kitchen, patio and servants quarters downstairs. Although built in the traditional post and beam construction of the north-east, modern Thai architectural design is evident in both the form and layout. The Thai authorities were very co-operative in providing a house which would suit a New Zealand housewife. As an example, in other projects, stairs to bedrooms were external to the main structure while in this design they are internal. A hot water system (using a New Zealand hot water cylinder), air conditioning, refrigeration, and a potable water supply are provided. Cooking is by butane gas stove and local charcoal cooker. When the project ends, these houses will become part of the District Highways Depot, meanwhile they will be regarded as model homes which could encourage the building of similar types of new housing in the north-east.

Medical eligibility standards are fairly high, and the upper age limit for posting is 45 years. The scale of vaccinations for personnel and dependants was considerable, comprising smallpox, TABT, polio, tuberculosis, diphtheria, cholera, typhus, yellow fever, plague, influenza, and hepatitis prophylaxis. Local medical cover has been arranged at Maha Sarakham with provision for air evacuation to Bangkok, or to Korat City where a US Army field hospital is located. All New Zealand adults have been encouraged to attend first aid classes.

Equipment. The selection of equipment was made following the calling of competitive tenders both in New Zealand and overseas. In drawing up the specification for each item of equipment, it was necessary to take into account both the location of the project and the experience of the operators. As each specification defined the required machine characteristics and also the servicing required, tenderers were expected to produce evidence of their capacity to provide an adequate range of spare parts, and allied services. Equipment of sound modern design, reliability and performance with a good service backing was sought, and it transpired that a suitable range of competitively priced equipment was offered. In view of the remote location of the road 400 miles north-east of Bangkok, good workshops, and spare parts facilities are necessary if down time and loss of production and unnecessary frustrations are to be minimized. A project workshop is being established at Maha Sarakham with an advanced workshop near the roadhead. At Bangkok and at other supplier "outlets" in the north-east, manufacturers are expected to provide specialized facilities and repair services. Field repairs will be carried out by RNZEME tradesmen attached to 5 Specialist Team, assisted by Thai personnel under training.

The major items so far purchased by New Zealand are five 150 hp angle and tilt dozers, four 115 hp graders (oilclutch), five 21-yd motorized scrapers (two twin-engined, three elevating type), two 2-yd frontend loaders, two 25,000-lb towed rubber-tyred rollers, one 75 cwt towed vibrating roller, one self-propelled soil stabilizer, and two self-propelled pneumatic-tyred rollers. These items, together with the workshop equipment and tradesmen's tools, soil testing and survey equipment, and additional earthmoving equipment and spares to the value of £100,000 yet to be purchased, comprise the bulk of the New Zealand equipment contribution. Other equipment is being provided by the Royal Thai Government.

Part Four—Design and Construction Aspects

A 6 metre pavement on an 8 metre formation has been adopted for the Borabu-Wapi Pathum leg of the road, and it is planned that the pavement crown will be formed at least 70 centimetres above flood water level. It is thus expected that earthworks will, on average, amount to 11,000 cubic metres per kilometre in flat to rolling terrain, with heavier fills being required on flood plains, which vary in width from several hundred metres to as much as 10 kilometres.

Design criteria are as follows:—

(*a*) Design speed 70 kph
(*b*) Maximum superelevation 0.1
(*c*) Maximum gradient 8 per cent
(*d*) Design wheel load 10,000 lb
(*e*) Bridge width 8 metres
( )) Design bridge loading H20–S16.

A typical road cross section is illustrated in Fig. 7. Local materials are likely to be satisfactory for subgrade, although some discrimination is necessary. For base and top courses suitably blended soil aggregate or soil cement is to be used. The naturally occurring aggregates, from lateritic sequence, or from terrace gravels, are found in relatively thin layers of only a few feet. Quality is variable and great difficulty has been experienced in locating any appreciable deposits close to the road alignment. Laterites generally possess poor gradings, variable bearing strengths, and fairly high plastic and liquid limits. At the time of writing the soils laboratory equipment had not arrived and complete engineering analysis of materials has not been undertaken. However, whatever the sources, gravels from each pit will require thorough mixing to obtain material of reasonably consistent quality and to conserve resources.

Pipe culverts in the north-east are commonly manufactured at roadside up to 1 metre diameter. They are unreinforced and laid at falls of $\frac{1}{2}$ to $1\frac{1}{2}$ per cent. In many cases they serve simply as equalizers, being laid in groups of two to five.

Part Five—Conclusion

This project will contribute substantially to the social welfare and economic progress of the people of the north-east, as well as training local personnel in road construction techniques and use of heavy equipment.

Remote villages and towns will be linked with provincial capitals, while farm and household industry and production will tend to increase and become more diversified. It will contribute to the development of the productive capacity of the people in these remote areas and stimulate such social benefits as more accessible health and sanitation facilities; faster transport, communication and acquisition of technology; introduction of more modern methods of agriculture; more accessible educational facilities, and better leisure and recreation.

More broadly, it will contribute to the economic development and stability of the region, and thus further the aims of the Colombo Plan.

The need for roads in Thailand may be gauged from the fact that there is only 1 mile of road for every 3,500 people in Thailand compared with 1 mile for every 1,660 in Burma and every sixty in the United States of America. If the adequacy of the roading system is taken as a measure of the prosperity and progress of a country, there is ample cause for feeder road projects of this type to be undertaken. It is hoped that the Thai–New Zealand project will benefit the people of the north-east in the ways already described.

Acknowledgements

The writer wishes to acknowledge the assistance given by WO I L. A. Skelton, RNZE, and Mr J. J. Stephen, Army HQ, in the preparation of maps and drawings and by Lieut H. E. Wedde, BE (Civil), RNZE, in providing the photographs taken by him during his initial survey of the first leg of the feeder road.

TABLE 1. *Rainfall—Feeder Road Project* (*a*)

Month	Maha Sarakham		Buriram	
	Rainfall—inches	No of Rainy Days	Rainfall—inches	No of Rainy Days
January	0.04	0.1	0.11	0.1
February	0.43	1.0	0.32	0.6
March	1.03	1.4	1.2	1.6
April	2.78	3.4	2.57	3.6
May	6.75	6.5	5.68	7.5
June	6.52	6.3	5.88	8.0
July	5.4	6.7	6.1	8.8
August	7.53	7.8	8.3	9.9
September	9.80	10.2	10.9	11.4
October	2.64	3.5	5.75	6.5
November	0.55	0.5	0.87	2.0
December	0.15	0.1	0.09	0.2
Annual	43.62	47.5	47.77	60.2

Note (*a*) Records from 1931–60

TABLE 2. *Summary of Events*

Date 1965	Event	Remarks
March–April	Engineering reconnaissance at route of proposed road and main and advanced base sites	Chief Engineer and RNZE liaison officer in conjunction with Royal Thai Government Officers
April–May	Negotiations and discussions with Royal Thai Government at Bangkok	NZ Embassy and attached RNZE Officers
July	Memorandum of Understanding effected	Between Governments
May–August	Detailed survey of first leg from Borabu to Wapi Pathum. Design of main and advanced base proceeds	RNZE liaison officer with graduate engineers of Thai Highways Dept
August	Tenders called for earthmoving plant on world wide basis	Stores Manager, Ministry of Works in conjunction with RNZE staff
September	Tenders accepted in Wellington, NZ, for supply of plant from USA, UK, Australia, and Japan	ditto
September	Contract signed in Thailand for the construction of the Thai–NZ main base at Maha Sarakham	
	Second in Command 5 Specialist Team (Road Construction) RNZE departed by RNZAF Hercules for Malaya *en route* to Thailand	For liaison duties in respect to construction of bases

TABLE 2—*cont.*

Date 1965	Event	Remarks
Late October	Mounting Instruction issued. Selected personnel and dependants commence vaccinations and inoculations.	
	Unaccompanied baggage of Team and dependants forwarded for shipment to Thailand	
November	Advance Party of one instructor (plant operation) and one instructor (plant repair) departed NZ for Bangkok to take delivery of plant arriving ex USA, UK, Australia, Japan	
	Team studies soil stabilization techniques with Tauranga County Council, NZ.	
December	5 Specialist Team concentrated at Linton Camp for final training, administration and documentation	
	Motorized scrapers arrive at Bangkok to be delivered by 400 mile road journey to Maha Sarakham by RNZE and RNZEME personnel	Advance Party
1966		
January	Main body—5 Specialist Team and dependants depart Whenuapai, NZ, for Korat City by RNZAF DC6	
	Married quarters at Maha Sarakham main base completed	In preparation for main body

Which Hut?

By Lieut-Colonel J. D. Townsend-Rose, MC, RE, BSc, AMICE

(With acknowledgements and apologies to the Consumers' Association)

Introduction

Covered accommodation for military forces has been needed for thousands of years, and development has progressed a long way since Julius Caesar first established his winter quarters at military stations in southern England in 55–54 BC.

In the last few years not only have military housing standards improved, but buildings are being used for ever-increasing purposes; vehicles are no longer kept in the open if cover can be provided, radio sets are operated and repaired in air-conditioned buildings, stores are kept in dehumidified sheds, and soldiers do not accept that dirt and sweat are necessary concomitants of living in overseas stations.

So the first part of our survey is "How much hut?" Table I lists the accommodation required in a hutted camp for a typical unit.

Available Types of Hut

Prefabricated building made its civilian debut in 1945, when many thousands of homes, still in use twenty years later, were erected to alleviate the housing shortage caused by the bombing of our cities, and it is again to the fore under the guise of "industrial housing". Most of these projects are in precast concrete which, due to its weight and bulk, is not a suitable medium for military housing which may have to be transported overseas, but there are a number of designs which lend themselves to military use and which are available "off the peg" from the manufacturers. Two such designs are included in this investigation, in addition to the standard military hutting equipments.

We have also considered huts made entirely from materials normally available locally, but we have excluded those which are rarely encountered, such as inflatable plastic domes, cement-sprayed hessian arches and other varieties requiring specialized plant, equipment or skills. For comparative purposes, we have also included two types of tentage and the full list of accommodation investigated is

Twynham	Temperate and tropical 32 ft
Nissen	16 ft and 24 ft
Tentage	GS Mk II and Marquee, Universal Store
"Australian" pattern	Made from local materials
Trade Type "A"	
Romney	
Marston	Low and High
Trade Type "B"	

Most of these are familiar to us all, but a brief description of three of them will help readers to make their own assessment of their value.

The Australian pattern was adapted in Borneo from a design in ME Vol VII, and consists entirely of timber and CGI. It is chiefly of value for a tropical climate since a great deal of emphasis has been laid on ventilation.

It has a 19-ft span, and is built in 10 ft bays—for comparison, an 80-ft-long hut has been selected. It can either be built on the ground with a concrete floor, or on wood or concrete piers (the latter are much more durable) with 6 in × 2 in bearers and ¾ in flooring. For barrack rooms the walls and roof are built to allow maximum passage of air, including a ridge vent, but for office blocks weatherboard walls can be installed, and with softboard liners the hut can be air-conditioned—this has been done in many of the offices at the HQ of the Borneo force. Plain barrack rooms were built there by contract at a cost of 17/6–20/- per sq ft, with raised wooden floors.

Trade Type "A" is produced by a well-known civil engineering firm and consists of a trussed framework welded from tubular steel sections. This framework is pinned at the ridge and at the foundations, obviating the need for heavy footings. Roof cladding is asbestos, and although wall sections are available, it may be cheaper to use conventional walls and doors.

The clear span between framework is 23 ft, but the overall span is 37 ft 6 in, giving 7 ft verandahs on each side, which can be extended to 11 ft if required. Bays are 13 ft 4 in long, and a standard dimension of 23 ft × 80 ft (6 bays) has been used for calculations.

Barrack blocks, with fixed wooden louvres and adjustable glass louvres as walls, fully lit and provided with fans, were built from this equipment in Brunei at a cost of 31/6 per sq ft by contract in 1964.

Trade Type "B" is similar to the Marston, but the roof trusses are formed of two lightweight trussed beams, fabricated from welded tubular steel, bolted together at the ridge. Spans range from 33 to 75 ft and bay length is 16 ft 8 in. Asbestos cladding is normally used, though CGI would reduce shipping cost.

A standard dimension of 50 ft × 183 ft (11 bays) has been used for comparative purposes.

The Requirements for Military Hutting

We have split our investigation into two parts:—

Hutting used for *living*, i.e. sleeping, messes and offices.
Hutting used for *storage*, including small QM stores and large depots.

Each of these two types has characteristic requirements, though some huts are suitable for both. Bearing in mind that military huts may be needed in any climate and in any part of the world, there is a large number of factors affecting the choice of a suitable design. We considered these to include:—

Living accommodation:—
- Ease of installation of heating and lighting
- Ease of installation of cooling fan: or air conditioner
- Comfort, under various climatic conditions
- Adaptability in shape of plan area
- Ease of provision of internal walls.

Storage accommodation:—
- Scope for using forklifts and overhead cranes
- Economical use of floor area
- Ease of installation of dehumidifiers.

Both types:—
- Initial cost per square foot
- Maintenance cost per square foot
- Shipping space required per square foot
- Degree of weatherproofness
- Security from pilfering
- Risk of fire
- Adequate natural lighting
- Speed and cost of erection
- Ease of dismantling and re-erection
- Ventilation
- Useful life when erected.

Comparative Statistics

We calculated the floor area of each standard hut, and ascertained its deadweight and shipping weight; we then calculated the amount of concrete required for its base, taking into account additional foundations where necessary, and made an estimate of its probable useful life before maintenance becomes unduly expensive, though this is subject to the climate and the use to which the hut is put. A summary of these statistics is shown in Table 2.

Comparative Costs

Since we are concerned with the cost per square foot of usable floor space, the basic cost of the hut, obtained from the manufacturers in the case of Trade Types "A" and "B", has been converted to a cost per square foot. To this must be added rail and probably shipping costs, and the cost of a concrete floor in most cases. It would have been instructive to add the cost of erection, but figures for this vary so widely according to country, military or civilian labour, convenience of site and so on that they are likely to be very misleading, and have been omitted. Actual figures encountered for the Australian Hut and Trade Type "A" are quoted above.

Table 3 shows a summary of costs.

Value for Money

Table 3 reveals some interesting facts. For example, the materials for an Australian hut cost less than just the rail and shipping costs of a Twynham; the latter is over four times as expensive, on a square footage basis, as a 24 ft Nissen.

Again, the materials for an Australian hut, delivered to site, cost less than tentage; owing to their short life, tents are most uneconomical if they are to be used for more than two or three years, and huts will be much cheaper in the long run, apart from being more comfortable.

The Twynham hut is a big advance on the Nissen for comfort and appearance, but the extra cost is by no means inconsiderable. The cheapest equipment hut of all, the 24 ft Nissen, is still held in some quantity in store.

Table 4 has been compiled weighing all the factors mentioned earlier. The relative assessments can only be a personal observation, since each man in his job will give greater or less weight to the various factors—the fireman will not have the same views as the designer, or the maintenance engineer, or indeed the tenant.

TABLE 1

Hutted accommodation required for unit similar to Infantry Battalion consisting of 30 Offrs, 40 WOs & Sgts, 700 R & F (incl 50 JNCO) and 50 Vehicles, based on Barrack Synopsis 1963.

Scale No		Sq ft
4	Barrack Blocks	53,280
6	Barrack Stores	5,350
10	Church room	260
14	Education Centre	4,135
19	Unit Garages (excl vehs)	750
22	Guardroom	1,455
24	Instruction rooms	3,100
25	Instructional sheds	4,500
26	JRC	10,340
29	Unit Medical Centre	1,135
30	R and F Mess	8,040
36	Officers Mess	9,365
	Kitchen	670
37	Offices	4,630
41	Miniature Range	2,400
44	Unit Stores (rations, QM, Sports)	6,160
45	Unit Technical Stores	7,077
49	WOs and Sgts Mess	6,610
	Kitchen	785
	Total	121,042
	Add 10 per cent for corridors and toilet facilities	12,104
		133,146

$$\text{Average sq ft per man} = \frac{133,146}{770} = 172$$

TABLE 2. *Comparative Statistics*

Type of Hut	Floor Area	Dead weight	Shipping	Concrete Base		Useful life
	Sq ft	Tons (a)	Tons (a)	Depth in	Vol cu yd	Years
Living						
Twynham						
Temperate	640	6.25	16:00	4	12	20+
Tropical	640	6.10	16:06	4	14.6	20+
16 ft Nissen	570	2.32	5:34	4	11	10
24 ft Nissen	1,550	5.20	9:13	4	26	10
Tent GS Mk II	196	0.08	0:15	4	2.4	1
Tent GS Store	875	0.50	1:20	4	10.8	1
Australian Hut						
Concrete floor	1,520	5.00	5:00	4	18.9	5
Wooden floor	1,520	8.35	8:14	piles only	7	10
Trade Type A(b)	1,840	8.53	14:28	4	25	20+
Storage						
Tent GS Store	875	0.50	1:20	4	3.6	1
24 ft Nissen	1,550	4.95	7:33	6	35	10
Romney	3,360	10.60	12:18	6	72	15
Marston Low	9,000	42.50	42:20	6	199	20+
Marston High	9,000	57.25	60:09	6	290	20+
Trade Type B	9,167	55.76	92:00	6	200	20+

Note: (a) Deadweight and Shipping tonnages include packing when this is used.
(b) Stanchions and roof only; requires locally-made walls.

TABLE 3. *Comparative Costs*

Type of Hut	Floor Area	Vocab Price 1965	Cost per sq ft of floor Area (1965)				
			Basic cost	Rail	Ship	Base	Total
	sq ft	£	s d	s d	s d	s d	s d
Living							
Twynham							
Temperate	640	900	28 0	9½	4 0	1 11	34 8½
Tropical	640	943	29 6	9	4 0	2 3	36 6
16 ft Nissen	570	180	6 6	4	1 8	1 11	10 5
24 ft Nissen	1,550	387	5 0	3½	11½	1 8	7 11
Tent GS Mk II	196	63	6 6	0½	4	1 3	8 1½
Tent GS Store	875	275	6 4	0½	3½	1 3	7 11
Australian Hut							
Concrete floor	1,520	280	4 7	3½	7½	1 3	6 9
Wooden floor	1,520	480	6 3	8	1 0	7	8 6
Trade Type A	1,840	580	6 4	(FOB)	1 3½	1 4	8 11½
Storage							
Tent GS Store	875	275	6 4	0½	3½	1 3	7 11
24 ft Nissen (no dormers)	1,550	307	4 0	3	1 0	2 3	7 6
Romney	3,360	1,144	7 0	3	10	2 2	10 3
Marston Low	9,000	4,321	9 6	4½	9	2 3	12 10½
Marston High	9,000	5,587	12 6	6	1 1	3 3	17 4
Trade Type B	9,166	4,403	9 7	(FOB)	2 0	2 3	13 10

Note: Costs are based on the following figures:—

Rail costs in UK	£4	per deadweight ton
Shipping costs	£8	per shipping ton
Concrete	£5	per cu yd, including shuttering
Timber	25*s*	per cu ft } used in Australian hut.
CGI	£4	per 100 f.s. } used in Australian hut.

TABLE 4. *Value for Money*

	Tropical		Temperate	
	Short Term	Long Term	Short Term	Long Term
Living				
Twynham				
Temperate	—	—	(a)	Poor
Tropical	(a)	Good	—	—
16 ft Nissen	Bad	Poor	Poor	Good
24 ft Nissen	Bad	Poor	Poor	Good
Tent GS Mk II	Good	(c)	Good	(c)
Tent GS Store	Good	(c)	Good	(c)
Australian Hut				
Concrete floor	Very Good	Poor	(b)	(b)
Wooden floor	Good	Good	(b)	(b)
Trade Type A	Bad	Very Good	Bad	Good
Storage				
Tent GS Store	Good	(c)	Good	Poor
24 ft Nissen	Good	Good	Good	Very Good
Romney	Poor	Good	Poor	Good
Marston Low	(a)	Very Good	(a)	Very Good
Marston High	(a)	Very Good	(a)	Very Good
Trade Type B	(a)	Very Good	(a)	Very Good

Notes: (a) Not suitable for short term, due to high cost.
(b) Not suitable for temperate climate.
(c) Not suitable for long term, particularly in the tropics, due to short life.

Conclusions

If, as military engineers, we are to pay regard to the taxpayers' pocket, the most suitable building for the project in hand should be chosen with great care.

There are believed to be 400 different kinds of prefabricated buildings produced commercially in UK, and many of them are ideally suited to military needs; delivery dates may preclude their use in some circumstances, but proper engineer planning and forethought, together with careful investigation of the alternatives available, will almost certainly produce better accommodation for the Services at a lesser charge on the taxpayer; only if these two conflicting criteria have been satisfactorily reconciled, has the military engineer done his job well.

Note by Editor:

Readers may care to compare the American prefabricated USAHOME, designed to meet American Service requirements overseas, described in this Journal under Technical Notes of the Military Engineer, November–December 1965.

Exploration for Water in the Aden Protectorate

By Major F. Moseley, RE (AER), MA, BSc, PhD, FGS

The Aden Protectorate, much in the news at present, has many problems, not the least of which is that of fresh water. Valuable assistance in this respect can be, and in fact is, provided by the Royal Engineers, in spite of well-known hazards during the shooting season, and the local people stand to benefit from efforts such as those of Captain R. R. Theobald and his well borers. In this article I hope to show how geological reconnaissance can help with these problems and also to emphasize that specialist knowledge is not invariably essential to the location of favourable water points. Indeed in many areas it should be perfectly possible for RE teams to make local assessments if a few general principles are applied, and Captain Theobald has adequately illustrated this point by his successful development of water points in the Al-Milah-Thumair region.

In Part I an account is given of the general geology and water-bearing potential of the various rock divisions, whilst Parts II to IV represent specific examples from three regions in which the problems differ considerably. That these regions could be surveyed at all at the present time is a testimony to the extremely efficient organization of the CE MELF, Colonel P. Drake-Wilkes, and the CRE, Lieut-Colonel W. D. C. Holmes and their staffs, and to the Commanding Officers of the FRA at Dhala and Ataq, who provided the essential escorts for cross country movement.

Part I—General Geology and Water Supply

Rocks ranging in age from pre-Jurassic Basement (metamorphic and igneous) to Tertiary and recent (sediments and volcanics) are to be found in the West Aden Protectorate (Fig. 1), but the precise distribution and local structures of these rock divisions is not known with certainty. Indeed south-west Arabia is one of the least known areas of the world geologically, and this means that geological and water supply problems can rarely be solved by reference to previously published work. A relevant bibliography is given at the end of this account. Z. R. Beydoun has summarized the geology of East Aden Protectorate, whilst G. W. Greenwood is the leading expert on the Protectorate as a whole, and particularly on West Aden Protectorate. D. Gear has considered water supply in a number of agricultural areas in a publication not easily obtained.

A summary is given below of the principal rock divisions and their water-bearing properties.

(*a*) *Basement* (*probably Pre-Cambrian*). These old rocks form a foundation upon which the more recent sediments rest, a foundation which is warped upwards in West Aden so that it is now exposed to erosion in many places. The basement is mostly of igneous and metamorphic origin and includes a variety of hard and resistant crystalline rocks such as granite, gabbro and gneiss. The basement areas are generally mountainous, difficult country with angular serrated ridges, separated by steep-sided wadis. They are mostly unfavourable rocks from the point of view of water supply, being impermeable, although water may be transmitted along the fairly numerous fracture zones.

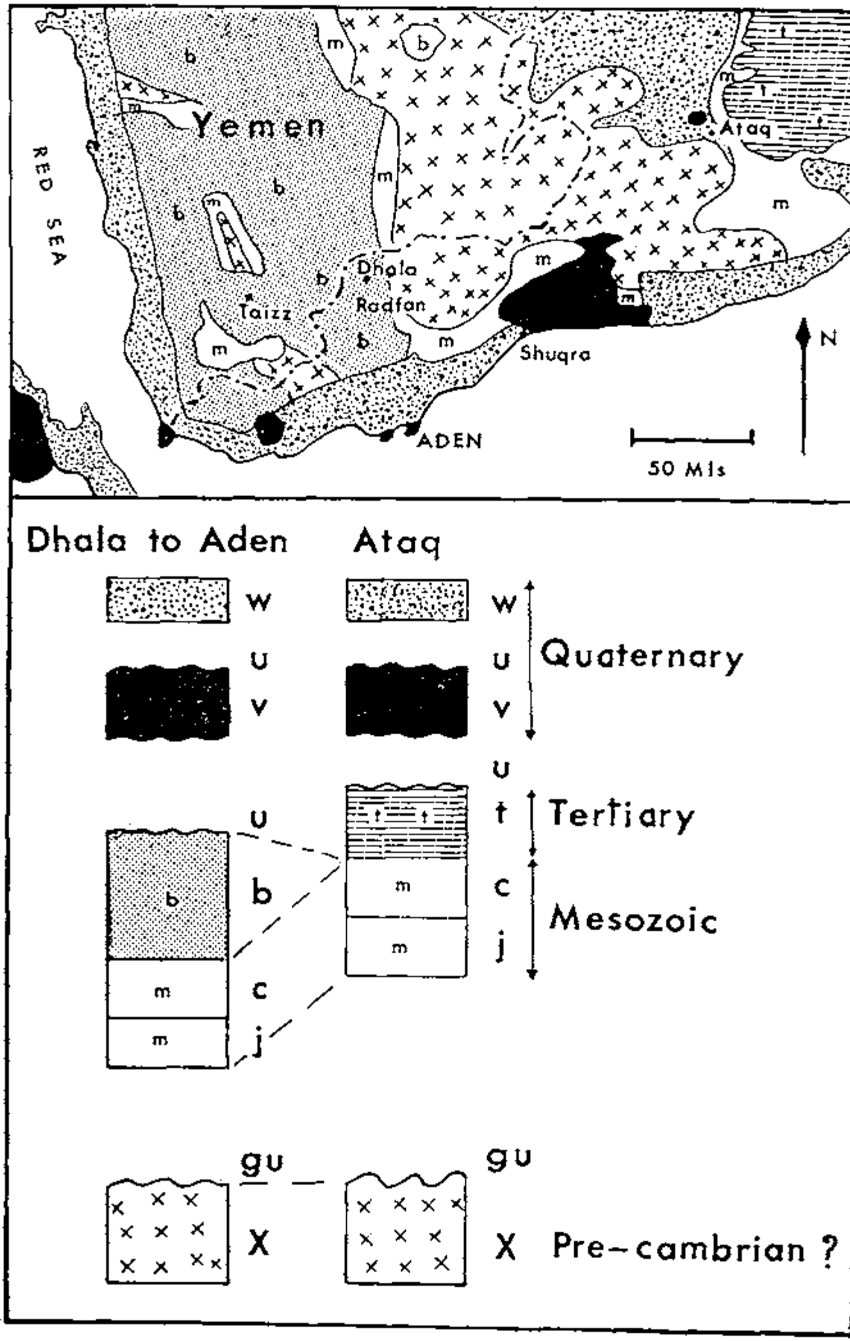


Fig. 1. Geological map and typical rock sequences in S.W. Arabia.
W = Wadi, dune and coastal fan sands and gravels.
v = Recent volcanic rocks.
t = Lower Tertiary limestones.
b = Cretaceous volcanic rocks (basalt).
c = Cretaceous sandstones.
j = Jurassic limestones.
x = Basement, mostly Pre-Cambrian (granite, gneiss etc).
u = Unconformity; gu=great unconformity.

The object of a preliminary water supply survey, should it be concerned with these rocks, would be to locate such fracture zones, certainly no easy matter and requiring specialist advice.

(*b*) *Mesozoic.* Palaeozoic rocks appear to be largely absent from south-west Arabia and there is thus an enormous gap in time (at least 400 million years) between the highly-contorted and re-crystallized Pre-Cambrian basement and the relatively undisturbed Mesozoic sediments. The junction between these two units is designated a "great unconformity" on Figure 1.

Jurassic and Cretaceous sedimentary rocks are of widespread occurrence, particularly in East Aden Protectorate, but also in faulted blocks in West Aden Protectorate, where they are followed by a thick development of Cretaceous volcanic rock.

In East Aden the Cretaceous sandstones can be particularly important aquifers, given the right geological structure, since they are extremely porous. This condition obtains in the Hadramaut where the rocks are flexed into a broad shallow basin into the centre of which the water flows naturally. Ataq is unfortunately on the western margin or rim of this basin and although the Cretaceous sandstones are to be found there, they are not water bearing (see Part IV).

In West Aden Mesozoic rocks are of more restricted occurrence but there are still quite large areas of limestone, clay, sandstone and basalt lava, which have been dropped down into the basement along zones of fracture. In the Radfan area (Part III) Jurassic limestones alternating with clay are succeeded by sandstone and a thick pile of Cretaceous basaltic volcanic rocks, the whole sequence dipping (inclined) south west at about 20 degrees. Mesozoic rocks also outcrop about 50 miles north-east of Aden, where Jurassic limestones again dipping south at about 25 degrees, give rise to strong north-facing escarpments and southerly dip slopes, whilst around Dhala there is exposed more than 10,000 ft of Cretaceous basalts (Part II).

The only really favourable Mesozoic aquifers in West Aden are the sandstones, although the limestones and to a lesser extent the volcanic rocks could yield water under some circumstances, particularly along fracture zones.

(*c*) *Lower Tertiary* (*Palaeocene and Eocene*). Thick scarp forming limestones (see Part IV Ataq) followed by limestone and clay, are widespread in East Aden, where they rest on the Cretaceous sandstone. They are not porous and only likely to transmit water along fissures and fractures. Rocks of this age and later Tertiary sediments are not common in West Aden.

(*d*) *Late Tertiary to Recent Volcanic Rocks.* Extinct volcanoes and associated lavas and ashes of recent date are found in various parts of the Protectorate, including Aden itself, the most extensive area being the hinterland of Shugra. They are nearly all of basaltic composition, and in their water-bearing properties will resemble the Cretaceous basalts in being generally unfavourable.

(*e*) *Recent wadi, fan and deltaic deposits.* The present-day arid climate with the occasional severe storm has resulted in erosion of the mountains with deposition of great thicknesses of detritus along the wadi floors and as alluvial fans and deltas cross the coastal plain. These deposits (gravels, sands and silts) range in thickness from a few tens of feet in smaller wadis, to several hundred feet in larger wadis and to more than a thousand feet along parts of the coastal plain. It is these porous unconsolidated sediments that yield by far the greater part of the Protectorate's underground water. The occasional heavy rain has a rapid run off from the bare mountains and is quickly absorbed into the sediment of the wadi. The recharge is often considerable since rainfall in the high mountains of the north west is appreciable and much of this rainfall eventually finds its way via the wadis to the coastal fans and deltas. Practically all the wells and boreholes now in use are situated in these recent deposits, but in the majority of cases the well only goes a few feet below the water table, tapping the unconfined water. Such wells depend a great deal on the "last rains", and are liable to go dry on occasions. In many areas deeper boreholes to tap the confined water in lower gravel beds would be feasible, with less reliance on the floods of the previous summer and more on the regional average over a number of years. If this were done a careful watch on salt content would be necessary, since this is frequently higher in deeper water.

The greatest difficulty in assessing water prospects in many wadis lies in determining the areas of maximum water concentration and flow in the lower levels of the gravels. Determination of the lithology (type of rock) and shape of the rock floor beneath the wadi deposits are of obvious importance since flow and "ponding" of underground water will be influenced by this. Rock outcrops adjacent to wadis often give important clues in this respect (see Parts II, III and IV), whilst a large catchment area, confluence of wadis, location on the outside of a bend etc, will be favourable indications. In many cases, however, the final answer (short of a large number of boreholes) is a geophysical survey. Either seismic or resistivity methods could be used, the former making use of "artificial earthquakes" would be capable of determining the shape of the rock floor and the positions of buried channels at the base of wadi deposits, a method particularly effective if the rock floor has very different physical properties to the gravel (for example where gravel rests on basement rocks or on lava). The latter method (resistivity) is capable of determining the presence and depth of water-bearing gravels as well as other changes in rock properties.

It should be noted that the salinity of the water in most parts of the Aden Protectorate is not high enough to present as serious a problem as in some desert areas. Further exploitation, however, could well alter this situation and salinity should at all times be checked. Field salinity test kits can easily be made up for this purpose.

Part II—Dhala

Dhala, situated in the mountains near the Yemen border, receives an appreciable rainfall for this part of the world (10–15 in) but this is not sufficient and there is a definite water shortage. The area to be considered consists of a broad north-south valley or complex of alluvial wadis at about 4,500 ft, surrounded on all sides by rough rocky hills of high relief, several thousand feet in the case of Jabal Jihaf, with Dhala itself at the watershed between north and south drainage (Fig. 2).

A. Geology

Geologically the whole region is formed of older (Cretaceous) volcanic rocks, predominantly basalt lava flows with subsidiary coarse basaltic agglomerate (fragmental rocks formed by explosive volcanic action) and finer grained volcanic ash. These rocks form a bedded or layered succession with lava flows and agglomerates resting upon each other to form a thick pile. The

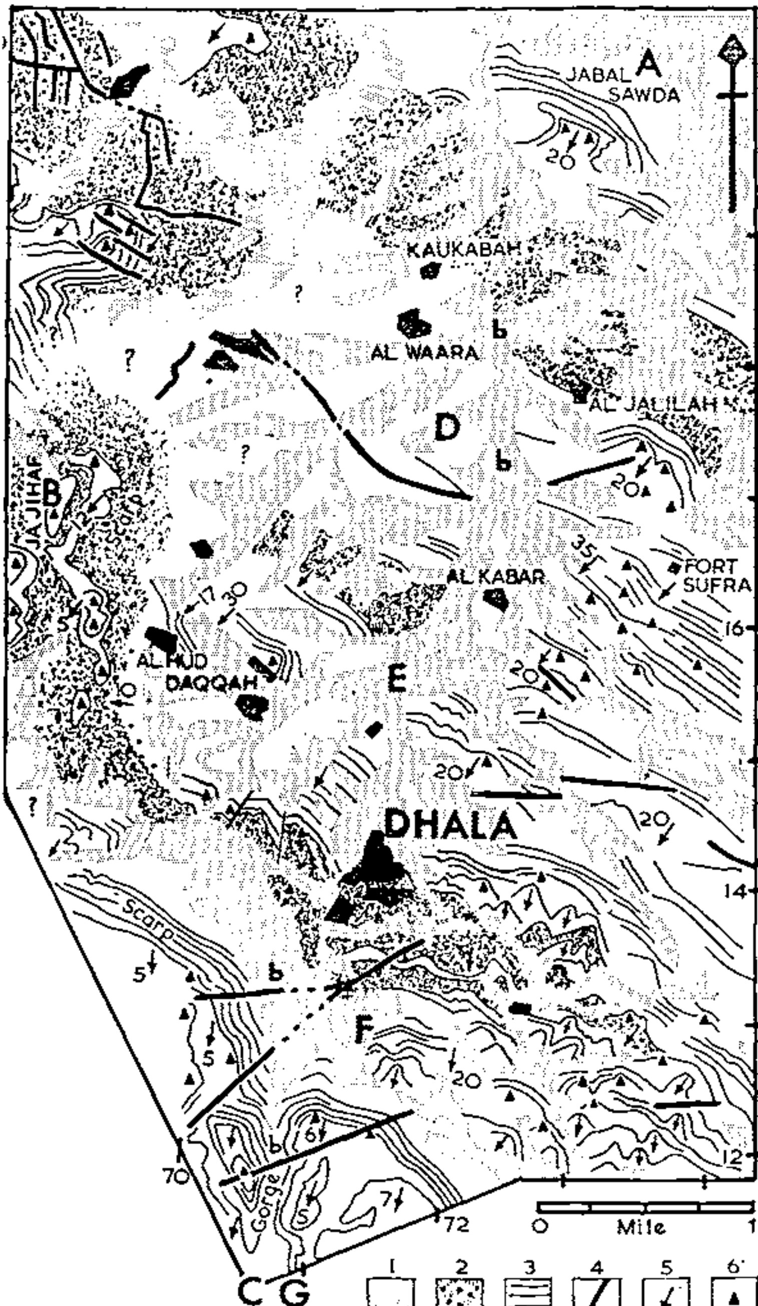


Fig. 2. Geological map of Dhala. Sections AB, AC, DE and FG are shown on Fig. 3.
1. Gravel, sand and silt of the wadis. Mostly cultivated in banked and terraced fields.
2. Volcanic agglomerate and ash.
3. Basalt lava flows showing bottoms of flows where possible.
4. Dykes.
5. Angle of dip of strata.
6. Prominent peaks and summits.
b. Best positions for deep boreholes. Villages are shown black.

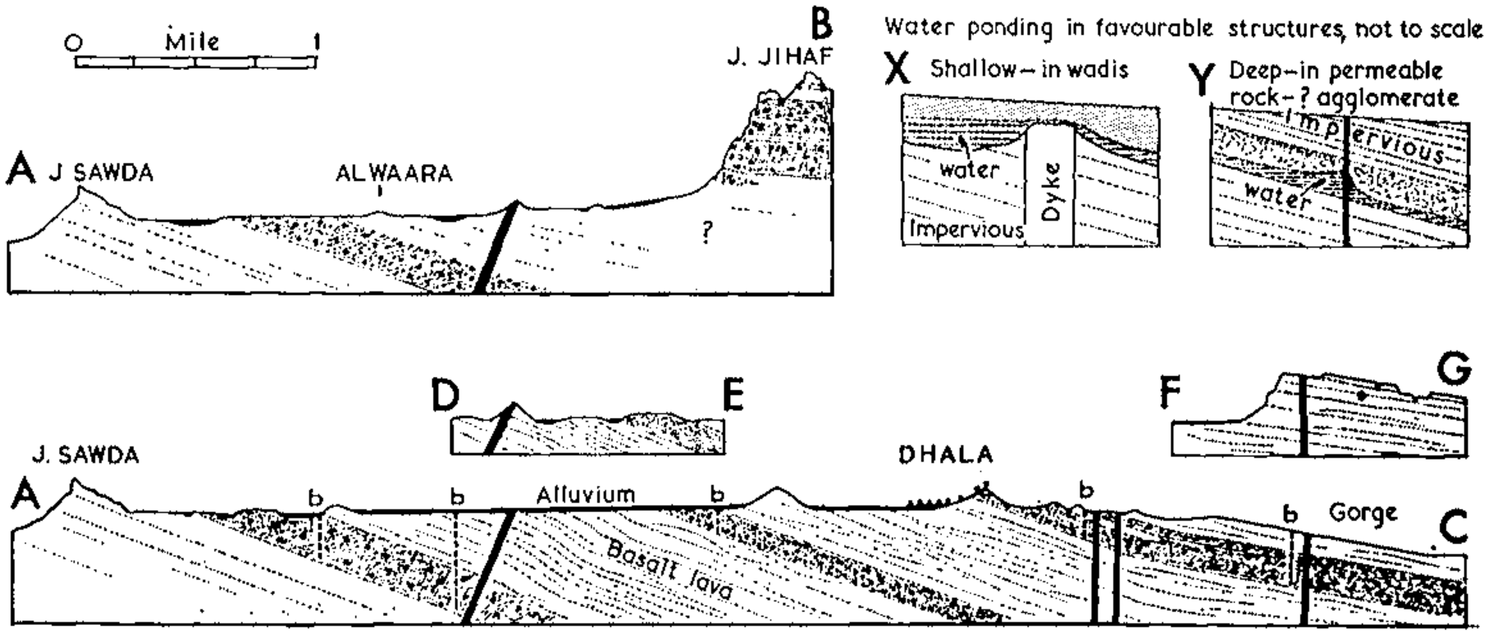


Fig. 3. Sections across the Dhala Valley. Key as for Fig. 2 except where indicated.

whole succession, tilted by earth movements subsequent to formation, is now inclined at angles of 15 to 25 degrees to the SSW, whilst recent erosion has cut through the rocks, exposing a thickness of more than 10,000 ft between Jabal as Sawda in the north and the gorge south of Dhala (Figs. 2 and 3). One further important feature is the series of subvertical dykes which cut cleanly through the other rocks.

Recent erosion, in addition to revealing the lower layers of the volcanic pile, has sculptured out the wadi systems, most of which are alluvial filled (gravel, sand and silt). These deposits are typically between 20 and 50 ft thick, whilst individual wadis are generally about a quarter of a mile wide and are everywhere terraced for cultivation. Further details of the types of rock are given below.

(*a*) *Basalt.* There are two types of basalt lava in this region, that occupying the greater part of the area from Jabal as Sawda in the north to south of Dhala, and an overlying type forming the massive escarpments and gorge south of Dhala.

The former consist of successive flows of olivine basalt lava each on average about 20 ft thick. Most flows are made up of a central part of hard black basalt with some clearly visible green crystals of the mineral olivine, and, on microscopic analysis, an average of 4 per cent of the highly magnetic iron mineral magnetite. The effect of these rocks on mine detectors will no doubt be appreciated. Above and below this (the top and bottom of each flow) the rock is highly vesicular (a sponge or pumice-like texture caused by escaping gas bubbles) and it is also thoroughly permeated by soft green chloritic minerals formed from decomposition of the basalt. In this condition the rock is soft, crumbly and readily weathered, the overall result being a characteristic "trap" or "stepped" topography of alternating hard and soft bands.

The massive scarp forming basalts in the south contain no olivine and have fewer vesicular layers. Magnetite is also less common, although there is still a fair percentage of other iron minerals present.

(*b*) *Agglomerate and ash.* Formed by explosive action, these rocks are interlayered with the basalts, but as can be expected, each layer is of varying thickness depending on the position of the volcanic centre responsible for the eruption. All outcrops of these beds have certainly not been located, but the general distribution is shown on Fig. 2. The thickest development is in the north near Al Jalilah, and in the cliffs of Jabal Jihaf, extending to beyond Dhala. There are less extensive outcrops at a number of other places.

The rocks include compact and rubbly varieties made up of fragments several inches to several feet in diameter, finer grained ashes, rather like sandstone in texture, and a few thin beds of ashy sandstone. It is conceivable that boreholes into some of these formations could produce water. (See below.)

(*c*) *Dykes.* These are near-vertical sheets of igneous rock varying in width from a few inches to 50 or 60 ft, and generally trending either NW or SW. Their composition varies from high silica rock such as rhyolite (almost glass) to trachyte (with much larger crystals) and is completely different from that of the surrounding basalt. Many of the dykes are massive, not seriously fractured and may be expected to act like dam walls, ponding back water.

(*d*) *Other rocks.* Interesting geologically, although of no significance to water supply, are the banded pitchstone sills (high silica glass) which occur on Jabal Jihaf.

(*e*) *Wadi alluvium and channels.* Adding to the previous comments on wadi deposits, it may be noted that there are few well-marked wadi channels crossing the alluvium, and fields with banked edges usually extend from one side of the wadi to the other. Since there is a fair rainfall it follows that most of the run off is absorbed quickly by the wadi deposits and underlying solid rock and should therefore be available for water supply purposes, but on the other hand the Dhala Valley is more or less at the watershed and the catchment area for drainage is small.

B. Water Supply

This resolves itself into two categories already briefly mentioned, first water from shallow wells or boreholes in wadi alluvium and second the possibility of water from deep boreholes in the solid rock.

(*a*) *Supplies from wadi alluvium.* Extensive supplies are already drawn by local inhabitants for use in irrigation etc, the water being largely taken from shallow wells 30 to 50 ft deep. These wells are sunk through the wadi alluvium and are often taken a few feet into impermeable solid rock which acts as a sump. Much of the wadi deposits I was able to inspect had a relatively fine-grained matrix and water flow through them is, therefore, likely to be slow. Wells in such deposits are unlikely to have a high yield but, since rainfall is appreciable, a steady supply can be expected. It follows from the above that wells could be relatively close together without seriously affecting individual yields, and it is probable that the wadis are capable of increased yields by sinking more wells. It is clear that not all points on the wadi floors will be equally favourable but no doubt well sinking over the centuries by local people will have determined by trial and error those locations which yield the most abundant water supplies. Further exploitation could be attempted with the following fundamental principles in mind:—

(i) The greater the catchment area the better.

(ii) Constrictions in the wadi floors caused by hard rock (resistant lava flows or dykes) may result in "up-wadi" basins of thicker alluvial deposits and correspondingly greater amounts of water.

(iii) Junctions of wadis are often favourable sites.

(iv) With slow flow into wells or boreholes yield can be increased by headings or collecting galleries, rising gently from the bottom of the well. This gives a greater collecting area for a single well, but of course there are difficulties of construction.

(*b*) *Supplies from the solid rock.* There is no doubt that the basalt lava flows and associated rocks of this area are not favourable to the preservation of large quantities of water, but before finally deciding empirical evidence is needed from a number of trial boreholes in the more favourable localities.

(i) The lava flows are for the most part massive, impermeable rocks, but the vesicular and somewhat porous tops and bottoms of the separate flows (typically about 20 ft thick), may transmit a certain amount of water.

(ii) The agglomerates and ashes are fragmental and are likely to be better aquifers than the basalts. A very high water yield does not seem likely but this conclusion is not necessarily final since there is little information from boreholes as yet. With patience and a number of trial holes it is indeed possible that a good supply could be obtained, but I suspect that the boreholes would need to be at least 600 or 700 ft deep.

The two thickest agglomerate formations have been mentioned above. The

Jalilah formation could be conveniently penetrated in the wadi bottom near Jalilah whereas the Dhala formation could be reached by a deep borehole in the gorge south of Dhala. There is an advantage here of a "down dip" dyke "dam wall". (Fig. 3.)

(iii) Fractures (joints etc). It has been previously noted that the rocks of Dhala are tilted to the SSW at angles of 15 to 25 degrees. The majority of the fractures are bedding joints parallel to the inclination of the strata, and water will tend to seep along them (slowly, since they are not open fissures) as well as along the more permeable bands.

(iv) Effect of dykes. The numerous vertical dykes described above will provide barriers to any down dip flow of water through the lavas and ashes, acting rather like dam walls in fact (see above). Greater amounts of water would, therefore, be expected on the up-dip or northern side of the dykes as shown in Fig. 3.

(v) Local concentration by wadis. The greater part of surface water flow is along the wadis and because of this there are likely to be larger water supplies in the solid rocks beneath the wadi floors, rather than away from them. Deep boreholes into the solid rock should therefore be in favourable wadi sites also.

(vi) Summary of favourable situations:—

(*a*) Sites should be "up-dip" of strong dykes.

(*b*) Sites should be in large wadis, preferably with large catchment areas.

(*c*) Boreholes should be deep enough to intercept the more permeable horizons, the depth of which can be calculated from the outcrop position and the inclination of the strata.

(*c*) *Future development.* In order to plan a water development programme in the Dhala Valley it is clear that more long term information is needed about existing supplies. For example, the location, depth, depth to water and yield of all wells should be determined (the latter at different times of the year). A start to such a compilation could well be made by army units stationed in the area, given a return to the relative stability of a few years ago.

Part III—Radfan

Radfan for the purposes of this account comprises the area shown on the map (Fig. 4), that is, between Thumair and Wadi Tayme. Like the Dhala region not very far away, it is an area of appreciable rainfall (probably about 15 in) and in fact there are one or two perennial streams. It is extremely mountainous with settlement in the valleys and particularly in the large cultivated tracts of the Wadi Tayme and along the wadi near Thumair.

A. Geology

The geology of the Radfan is rather complex and the rapid reconnaissance left many problems unsolved.

(*a*) *Pre-Mesozoic Basement.* There are two areas of pre-Mesozoic rocks in the south-east and north respectively.

(i) The south-eastern outcrop consists of dark coloured, relatively soft rocks which are impervious and deeply weathered into a variety of bad land topography (numerous irregularly-shaped steep hills with sharply-gullied flanks). Little is known about these rocks but they are probably basic schists and gneisses (metamorphic) and are unlikely to yield underground water. The alignment (trend) and the inclination (dip) of the bands is shown on Figs. 4

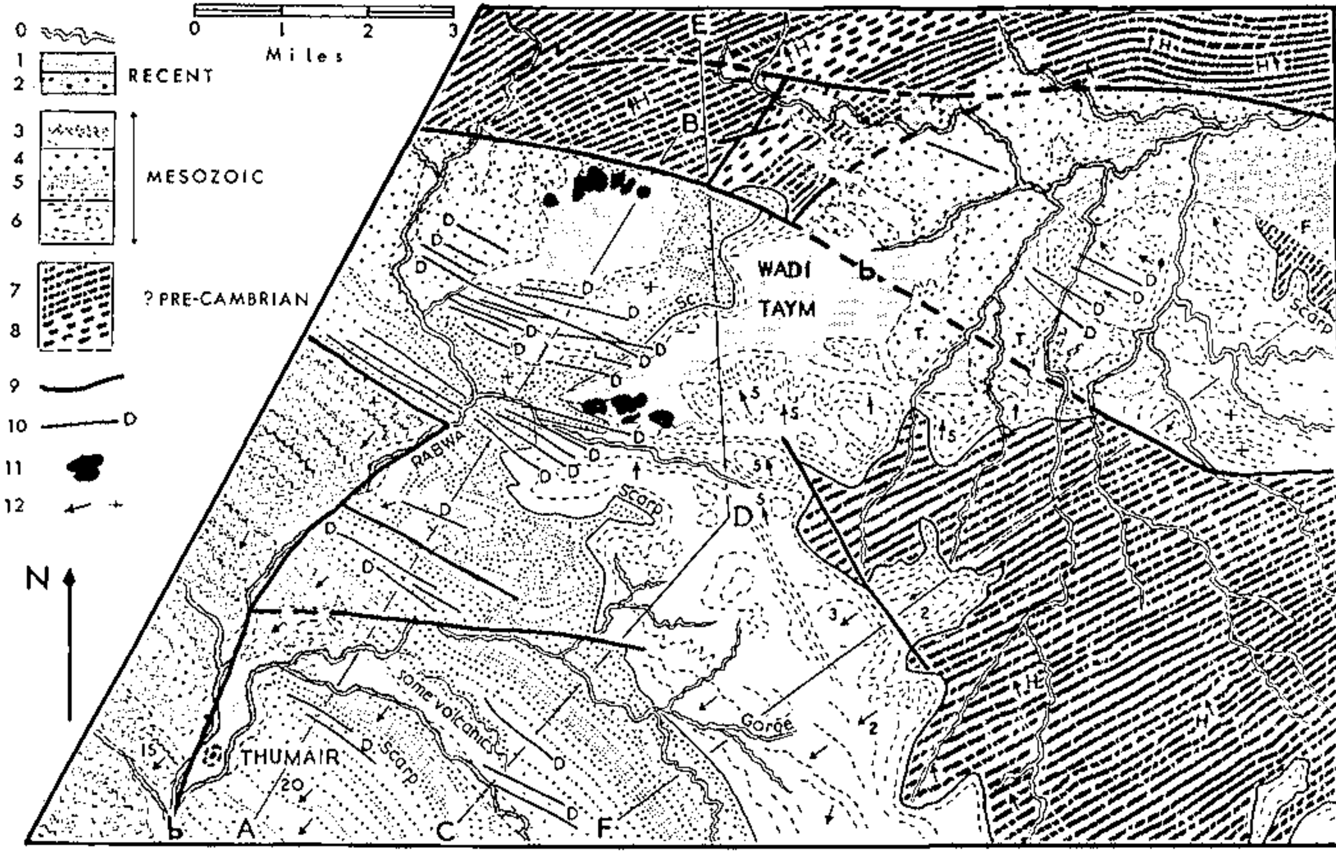


Fig. 4. Geological map of the Radfan Mountains. A-G—lines of sections on Fig. 5. b—two suggested borehole positions. 0—wadis. 1—alluvium and gravel of major wadis. 2—gravel spreads including terraces (T) and fans (F). 3—volcanic group with interbedded sediments. 4—sandstone and 5—shale of the Rabwa sandstone group. 6—Taym limestone group with interbedded shales. 7 and 8—Basement (?Pre-Cambrian). 7—probably schists in the south-east and gneisses in the north. 8—probably granitic gneiss. Trend of rock bands shown by ornament. 9—faults. 10—dykes. 11—igneous intrusions. 12—dip (inclination of strata in degrees. + where strata horizontal, H where inclination very high).

and 5. This area of exposed Basement is one from which the Mesozoic rocks have only recently been removed by erosion, and the sections (Fig. 5) show how the near-horizontal Mesozoic sediments must have been originally laid down upon it. This is an unconformity representing a time gap of hundreds of millions of years between the two groups.

(ii) The northern outcrop is separated from the Mesozoic rocks by large fractures or faults along which the strata have been displaced by at least several hundred feet. The rocks here are considerably harder than those of the south-eastern outcrop and form steep mountainous ridges. They are highly inclined, near vertical in places, and are mostly dark coloured (largely basic gneisses) except for one broad light coloured band (granitic gneiss, cf G. W. Greenwood). It is unlikely that they will yield underground water.

(*b*) *Mesozoic*. (i) Limestones and marls (probably Jurassic). Resting on the basement there is about 1,000 ft of limestone which is interbedded with thin bands of soft marl (clay). Immediately south of Wadi Tayme these rocks give rise to flat-topped hills with terraced sides, each terrace corresponding to the outcrop of a hard limestone band. A few miles south-east and east of Wadi Tayme, where the limestone rests on basement, there are considerable precipices (Fig. 5, F–G). They are not likely to be prolific water-bearing rocks, but where geological structures are favourable as in Wadi Tayme, moderate to good supplies may be obtained.

(ii) Sandstones (Jurassic to Cretaceous?). Several thousand feet of what is dominantly sandstone follows the limestone. Intercalated with the sandstones are a number of important shale beds, whilst it is probable that there are also occasional limestones and volcanic rocks, although no direct evidence for them has been obtained. These rocks form the flat-topped, steep-sided hills west of Wadi Tayme and on either side of the upper Rabwa gorge. Farther south they are inclined about 20 degrees to the south-west and give rise to the steep south-easterly trending ridges east of Thumair. The sandstones are porous and almost certainly will form the most important aquifer in this area.

(iii) Volcanic rocks (probably Cretaceous). These rocks, equivalent to those of Dhala, most probably rest on the sandstones, although this cannot be demonstrated here because of the block faulting. They include basalt lava, ash and some interbedded clay and limestone bands and outcrop north, west and south-west of Thumair. Water prospects will depend on occasional permeable layers and are not likely to be more than moderate.

(iv) Dykes. Large numbers of WNW trending dykes (probably of basaltic composition, but none have been sampled) are found particularly near the western end of Wadi Tayme. They may locally interrupt the flow of underground water and thus be of value to water supply as was explained in the section on Dhala.

(*c*) *Recent alluvium and gravel.* Gravel terraces occur along the flanks of the wadis and gravel cones spread downwards from the higher land. Alluvial spreads (cultivated) are to be found in all the larger wadis. These deposits will yield water from shallow wells, and many such wells are already in existence.

(*d*) *Structure.* Basement rocks were considerably disturbed by pre-Mesozoic earth movements. They are steeply inclined, mostly to the north-west, but swinging round to a northerly dip in the north of the area as shown by the structure-lines on Fig. 4.

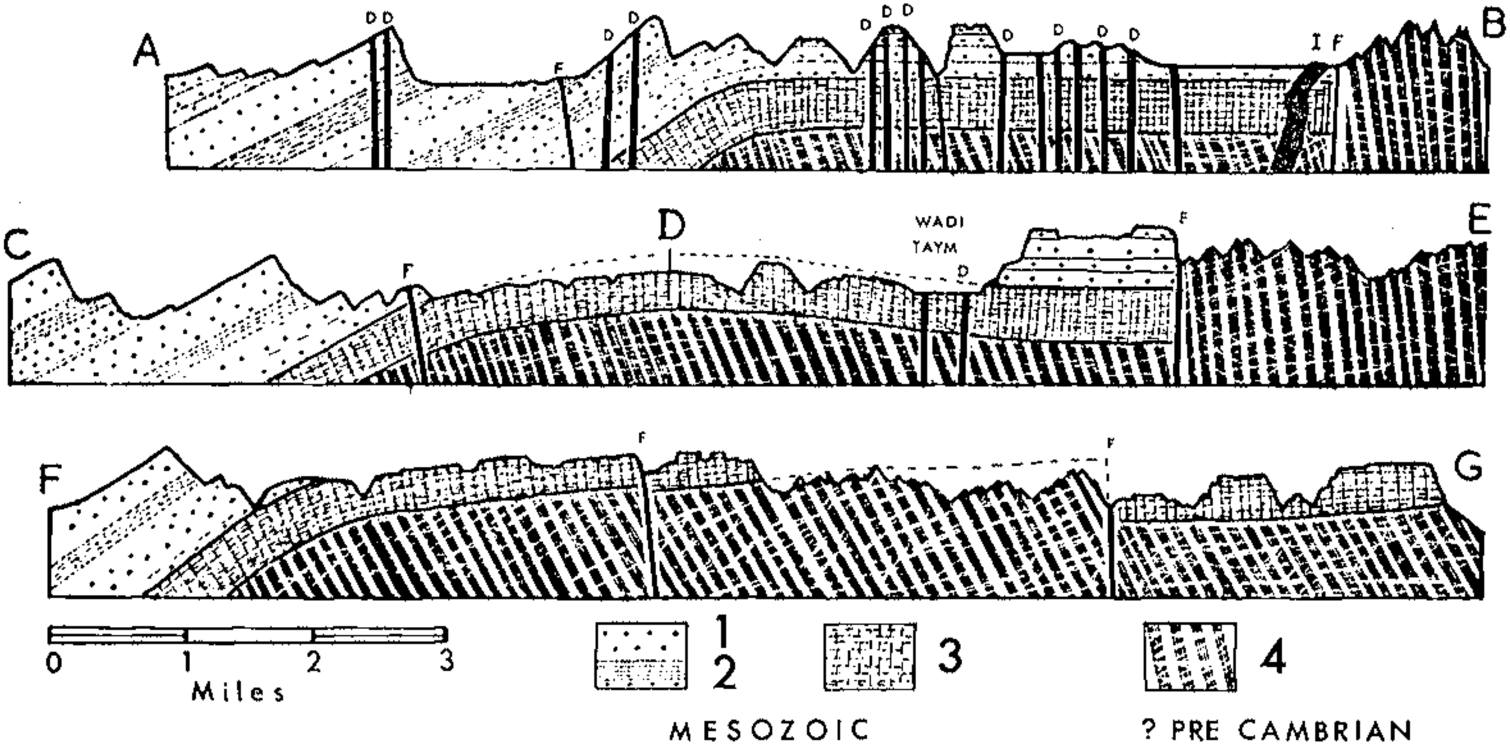


Fig. 5. Geological sections across the Radfan. Lines of sections shown on Fig. 4. Vertical scale approximately twice the horizontal scale. 1—sandstones and 2—shales of the Rabwa sandstone group. 3—Taym limestone group. 4—Basement, probably Pre-Cambrian showing approximate inclination of rock layers. D—dykes. I—igneous intrusion. F—faults.

Mesozoic rocks are near-horizontal around Wadi Tayme and locally are warped down into a shallow synclinal (basin) structure. Further south they bend over and are inclined to the south-west, typically at angles of 20 degrees.

Faults or fractures of major importance traverse the area and bring into contact rocks of very different ages. The basement is faulted against the Mesozoic in several places and at Thumair the sandstones are faulted against the volcanic rocks. These faults which will often permit free movement of water are of major importance to water supply.

B. Water Supply

Within the area of the map water can be expected from three sources as follows:—

(*a*) *Wadi Supplies* (*Alluvium*). Shallow wells in the sands, silts and gravels of the larger wadis will yield supplies of water. The principles outlined in the Dhala Report will apply, but it should be noted that the Radfan is more favourable since the catchment area and the wadis are larger than at Dhala, and the alluvial sands and gravels in the wadis are thicker.

(*b*) *Supplies in Solid Rock.* General comments on water-bearing prospects have already been given. The Mesozoic sandstones will be the important aquifers. They are thickly bedded, porous and water should drain "down dip", that is, to the south-west. Almost any deep borehole east of Thumair would intercept sandstone horizons and should give a good continuous supply of water.

The limestone is less satisfactory but a borehole in the centre of the synclinal basin in the Wadi Tayme should give a reasonable supply. It will be seen from Fig. 5 (section D–E) that this synclinal area together with the fault to the north will form a natural reservoir on the impervious basement.

(*c*) *Faults.* Many of the faults will act almost as open fissures for the transmission of water and this applies particularly to faults traversing such rocks as sandstone. Moreover as planes of weakness in the rock they are usually etched out by erosion, and thus followed by wadi, with wadi floodwater filtering straight into them. Where faults effect the sandstone successions supplies will be further implemented by natural drainage through the sandstone.

The most favourable borehole positions are along the wadi from the Rabwa Gorge to Thumair and beyond. It will be noted that near Thumair the dip of the sandstones is obliquely towards the fault, thus bringing in more water, and it is probable that deep boreholes hereabouts would yield large supplies of water. They should preferably intercept the fault.

Part IV—Ataq

Ataq, in a region of low rainfall is situated on the northern margin of the mountains at a point where a large north draining wadi system debouches on to the plain. The wadi or complex of wadis, about 3 miles wide at Ataq, is bounded on the SW and S by sharp hills of old basement metamorphic rocks, on the east by high escarpments of sandstone and limestone and is interrupted to the NW by the low extinct and eroded volcano of Jabal as Sawda.

The basement outcrops south of Ataq from a series of low north-south ridges and valleys, which extend northwards as a buried topography beneath the wadi deposits (Fig. 7). The relation of the wadi deposits, which exceed 100 ft in thickness, to the underlying rock and to the volcano of Jabal as Sawda is of fundamental importance to the development of additional water supplies in the area and is discussed below.

A. Geology (Figs. 1–2)

(*a*) *Basement* (*Probably Pre-Cambrian*). These rocks are mostly of metamorphic origin, but in the south are penetrated by a large body of igneous rock (gabbro), which extends beneath the wadi gravel at least as far north as Ataq. Here it can be seen at the bottom of the unproductive wells (Fig. 7).

The impermeable basement rocks are not likely to yield important supplies of water unless it should prove possible to tap an open fracture system beneath the wadi gravel. Fractures of this kind can be seen in the south-western outcrop with N and NW trends but there is little hope of locating them beneath the gravel of the main wadi.

(*b*) *Mesozoic and Lower Tertiary*. Jurassic limestones form a low north-south ridge (about 100 ft high) on the eastern flank of the Ataq wadis (Figs. 6 and 7). This ridge appears to be bounded by faults (fractures along which the strata have been displaced vertically) and the Jurassic rocks are thus brought against basement and Cretaceous rocks as shown on the sections (Fig. 7).

Cretaceous sandstones and lower Tertiary (Palaeocene and Eocene) limestones are seen in the high escarpments on the eastern margin of the Ataq map, and are separated from the Jurassic ridge by a north-south gravel filled depression. The sandstones form the steep boulder strewn slopes at the foot of the main cliffs. They are weakly cemented, extremely porous and would be an important aquifer given the right geological structure. In this region this is not the case since the strata are inclined very gently towards the east and their contained water drains in that direction, away from Ataq. The massive limestones rise vertically above the sandstone slopes and in turn are capped by steepish slopes made up of alternations of limestone and marl (calcareous clay) (Fig. 7).

(*c*) *Late Tertiary to Recent Volcanics*. The old volcano of Jabal as Sawda is the most notable outcrop of recent volcanic rocks and consists of a low eroded central boss surrounded by a plateau-like area of olivine basalt lava flows. The lava flows are thin and have been gullied through on the margins to reveal basement rocks beneath (Fig. 7). This volcanic mass is important in so far as it stands in the path of the north draining wadis, thus deflecting and concentrating the drainage into a narrow channel.

Other outcrops of volcanic rock are found south-east of Ataq, where there are a number of small basalt cones, in some cases with remnants of the craters still preserved. They are, apparently, associated with the line of fractures along the Jurassic ridge.

(*d*) *Wadi Deposits*. Periodic floods have transported masses of gravel and sand from the plateaux and hills into the Ataq basin. This material has been deposited as screes and gravel fans at the foot of escarpments, and as spreads of sand and gravel across the wadi floors, the finer elements being continuously redistributed by wind.

GEOLOGICAL MAP OF ATAQ (ADEN)

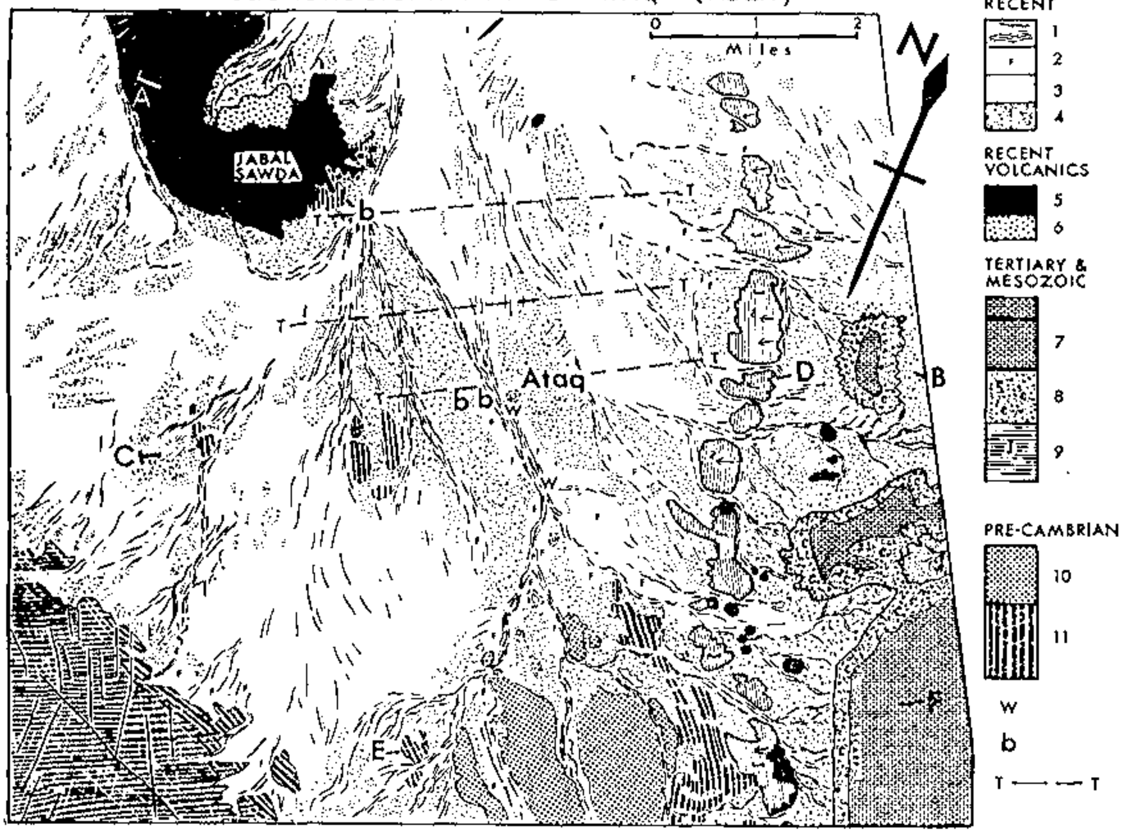


Fig. 6. Legend. A to F are lines of sections on Fig. 7. *Recent.* 1—wadis and drainage streamers. 2—fields banked to collect floodwater. 3—loose sand dominant. 4—gravel dominant. 5—basalt lava flows of Jabal Sawda and small basalt cones in south-east. 6—eroded vent of Jabal Sawda. *Mesozoic.* 7—Palaeocene scarp forming limestones below and Eocene limestones and marls above. 8—Cretaceous sandstone. 9—Jurassic limestone. *Basement, probably Pre-Cambrian.* 10—gabbro. 11—metamorphic rocks, schist, gneiss and marble. W—wells in main wadi. b—best borehole sites. T–T—lines for geophysical traverses.

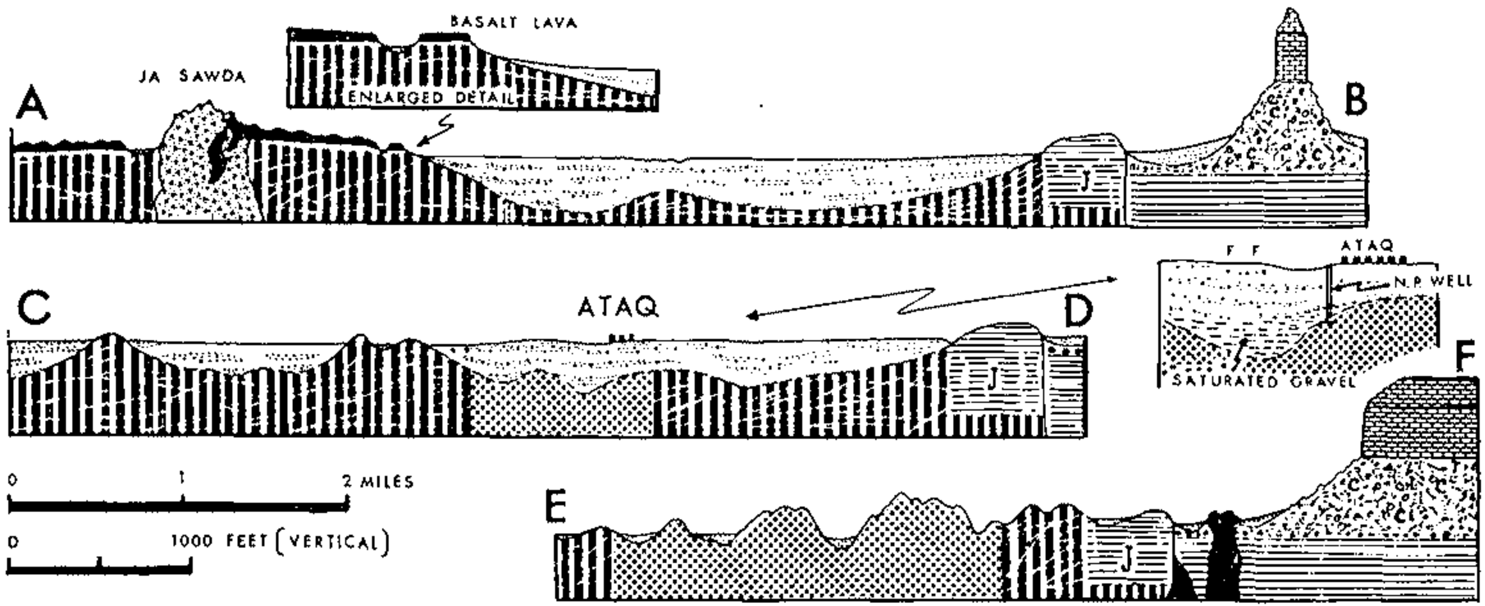


Fig. 7. Sections across the Ataq wadis. Legend as for Fig. 6 except where indicated. NP well—non-productive well.

These deposits must certainly bury an irregular topography of ridges and valleys similar in fact to the ridge and valley topography still visible south of Ataq. Indeed the highest points of the buried ridges are still visible in places (eg 1 mile SW of Ataq), whilst the adjacent buried valleys containing more than 130 ft of sediment (wells at Ataq) give some idea of the buried relief.

The geological map (Fig. 6) shows the surface distribution of the wadi deposits. The whole area between the Jurassic ridge, Jabal as Sawda and the basement ridges SW of Ataq is extremely flat, and it is particularly difficult to get a true idea of drainage directions from ground reconnaissance. It is not easy for example to decide whether the main drainage of the Ataq wadis is to the south-west or to the east of Jabal as Sawda. This is clearly revealed however on the air photographs, where wadi and drainage streamers show up distinctly. The streamers are bands of sand, not always channelled, supporting a variety of shrubs and a scatter of low acacia, and separated from each other by gravelly flats which may rise a few feet above the general level, and by wider areas of loose sand. The more obvious wadi channels tend to peter out north of Ataq and the floods clearly fan out beyond this point. The field systems, with low banked margins simply make use of the occasional flood, and there is no attempt to use underground water for irrigation. The whole of the wadi area is easily accessible to vehicles although some care must be taken when crossing the sand patches.

B. Water Supply

The search for additional water near Ataq must necessarily be confined to the wadi gravels, since the solid rocks hereabouts are not favourable. Periodic flooding covers the whole of the flat wadi area between Jabal as Sawda, the Jurassic ridge and the region south of Ataq, the water being absorbed quickly by the sands and gravels and gradually sinking to the base of the deposit, where it will be preserved. Considering that at the present only 5,000 gallons of water per day (from one well south of Ataq) are taken from a large wadi area of about 10 sq. miles, it would appear that there are extremely good possibilities of materially increasing the supply. The water at the base of the gravels will continuously migrate to the low points which will be the channels in the solid rock floor, comparable to the still exposed wadi channels 4 miles south of Ataq. The most favourable positions for water will be:—

(i) Where major channels join.

(ii) Where there is a constriction or obstruction which results in up-channel ponding of water.

It must be stressed that positions of buried channels are not necessarily related in any way to the present positions of wadi channels at the surface, and this can explain why wells in apparently good sites may be unsuccessful (eg the wells at Ataq village).

(a) *Surface Indications of Areas of Water Concentration*

(i) Ridge and valley topography. Consideration of the ridge and valley topography south of Ataq suggests a similar buried topography at Ataq itself with the high point of one basement ridge not yet buried and the possibility of two or more buried channels (Fig. 7). The alignment of these ridges and valleys is largely controlled by the alignment or trend of the harder and softer bands within the basement. The rocks in the ridge SW of Ataq trend NNW and it could be significant that the surface wadis tend to be aligned in this direction also.

(ii) The obstruction of Jabal as Sawda. Jabal as Sawda stands abreast of the NNW surface drainage, which is deflected to the east and north, between Sawda and two small outcrops $1\frac{1}{2}$ miles farther east (Fig. 6). The same deflection of drainage and concentration of channels (with possible confluence) will also apply to the sub-gravel drainage. The possibility of underground water hereabouts should therefore be investigated.

(*b*) *The Use of Geophysics.* It will be apparent that the preceding observations give only a general guide to the water prospects. More precise information would be forthcoming from a geophysical survey to which this type of wadi situation is well suited. If it is at all possible such a survey should be undertaken, traversing along the lines T–T on Fig. 6. Of the two methods outlined below resistivity would be cheaper and quicker but seismic would probably give a more definite result.

(i) *Electrical resistivity* (*Megger*). Resistivity of naturally occurring substances varies greatly, and the water content is the factor which probably has the greatest effect. Water saturated gravels of moderate salinity, such as occur in this region, will have very low resistivity compared with the dry gravels above and the impervious basement below. Providing the saturated zone exceeds 10 ft it should be detectable (together with the depth) by a Megger traverse. This method operates on the potentiometer principle and can register the resistivity at depths of up to 400 ft (the depth measured depending on the distance apart of electrodes which are inserted into the ground).

(ii) *Seismic.* Seismic methods depend on the generation of artificial earthquakes, generally by exploding a charge in the ground. Shock waves are transmitted through the ground as wave fronts and are refracted and reflected by discontinuities in the underground rock structures (shock wave velocities differ in different materials). The refracted and reflected waves can be picked up by sensitive instruments (geophones), the time taken is recorded and the depth to the discontinuities can be calculated.

The junction between the wadi gravel and the basement is a discontinuity ideally suited to detection by a seismic refraction survey. This would enable the positions of rock channels to be plotted and precise borehole points to be located. Apparatus capable of doing this work exists and is supplied to civil engineering firms, although it is rather expensive (several thousand pounds).

(*c*) *Some Conclusions and Recommendations.* Only one well of any consequence is available to Ataq village. This well, which gives about 5,000 gallons a day (but with little drawdown) is about 1 mile south of the village, with the track to it following the sandy wadi bed. There is an obvious need to develop an additional supply.

From the surface evidence the productive well would appear to be in the ideal situation near to the confluence of several wadis, and before the floodwater fans out on to the wide Ataq plain. However, considering the extent of the floods there is no reason to think that supplies would not be available farther north, and it is interesting to reflect on the failure of the five wells recently constructed on the wadi floor at Ataq. These wells are something like 150 ft deep and go beyond the base of the wadi gravel. The fact that they contain little water seems to suggest that they are not located on the "buried channel" (that is the surface channel is not above the buried channel (Fig. 7)).

Recommendations are as follows:—

(i) A geophysical survey should be the next stage of investigation, but should this not prove to be possible the following procedure should be adopted:—

(ii) Accurate measurements should be made of the depth of gravel in each of the five new wells and in the productive well. This will give some idea of the slope of the solid rock floor beneath the gravel.

(iii) New wells or boreholes should be sunk down to the rock floor 100 yds and 200 yds west of the present wells and the depth of gravel carefully recorded in each. This will give more information on the shape of the rock floor and position of buried channels with the chance of hitting one of the channels.

(iv) New wells or boreholes could be sunk in positions marked B (Fig. 6). In fact without geophysical help several boreholes would be desirable at each locality, arranged at (say) 100 yd intervals along the lines of the traverses T–T, with accurate measurements of gravel thickness in each case.

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Airfield Pavement Design

By Major K. Donaldson, RE, AMICE, AMBIM

The generally accepted method of airfield pavement design in the United Kingdom and in the Corps is based on the California Bearing Ratio of the subgrade from which a thickness of pavement required to support an Equivalent Single Wheel Load (ESWL) or an aircraft of a specified Load Classification Number (LCN). The LCN system was described in an article[1] in the December 1962 *RE Journal*. This article stressed the value of the LCN system both for the use of airfields by aircraft operators and as a design aid.

Since officers in Field Squadrons (Airfields) and in other appointments may be required to design, or check designs done to other systems, an outline of another system, the USA Civil Aeronautics Administration method is described. Examples of both design methods are given. These examples are only included to show the processes involved in pavement design and are not meant to indicate a correlation between the two systems.

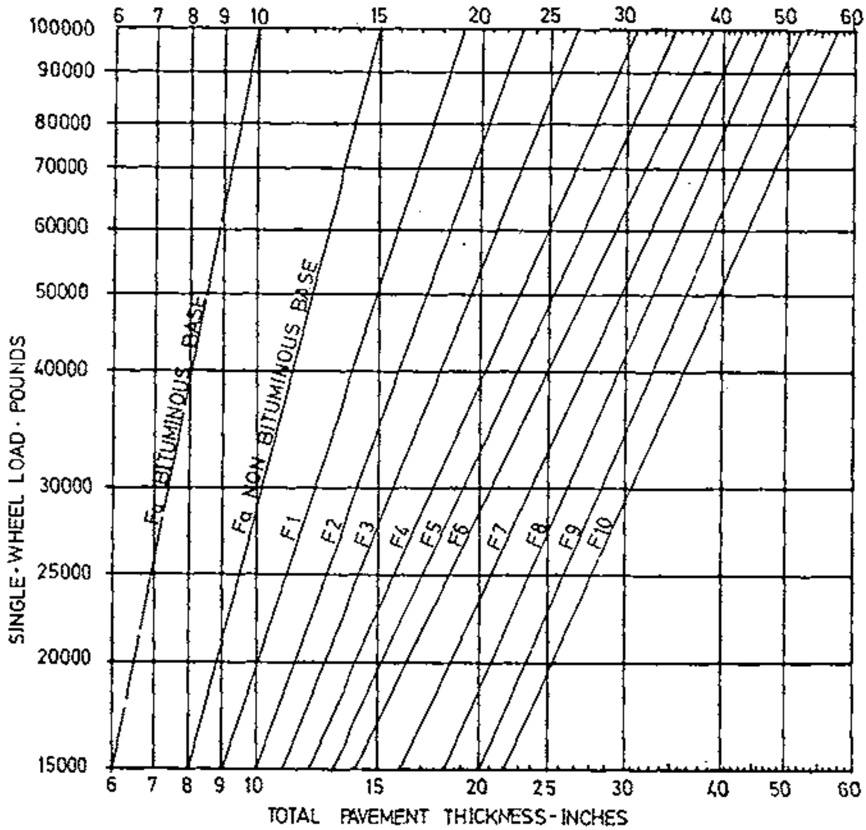
The location and construction speed requirements of future service airfield construction tasks will probably best be met by the use of flexible pavements. A flexible pavement is defined as generally consisting of bitumen or tarmacadam laid in one or more layers on a suitably consolidated soil. Cement stabilized soil is regarded as being a flexible pavement since it too has the characteristic small resistance to tensile stresses. The strength of a flexible pavement may be controlled either by the thickness and quality of the surface and base course, or if such components are not critical, by the total pavement thickness. The effect of tyre pressures is most pronounced in the surface and base course but thickness requirements do not vary much for small tyre pressure variations.

The USA Civil Aeronautics Administration (CAA) design procedure is based on a soil classification which utilizes a mechanical analysis and the liquid and plastic limits. Tests are carried out to identify the soil at the proposed airfield location, and its relationship to the properties of a soil of known performance and behaviour. Having established the relationship between the test sample and a "standard" soil, a pavement can be designed on the assumption that the soil at the proposed airfield location will have the same characteristics and degree of stability under like conditions of moisture and climate as a "standard" soil.

The tables[2] shown at Appendix "B" give the various "standard" soil groups arranged in increasing order of liquid and plastic limit. The tables also differentiate between granular and fine-grained soils. For each soil group there are corresponding subgrade classes, based on the *in-situ* performance of the particular soil as a subgrade for rigid or flexible pavements under different conditions of drainage and frost.

For reasons such as economy of cost and construction time, not all portions of an airfield pavement need to be laid to the same thickness; Fig. 1 shows the total flexible pavement thickness for taxiways, aprons and runway ends related to the "standard" soil; Fig. 2 shows the requirements for non-critical areas.

The thickness taken from Figs. 1 or 2 are the total pavement thickness including surfacing. The proper function of the surfacing is to provide a suitable wearing finish which will not unduly interfere with the aircraft per-



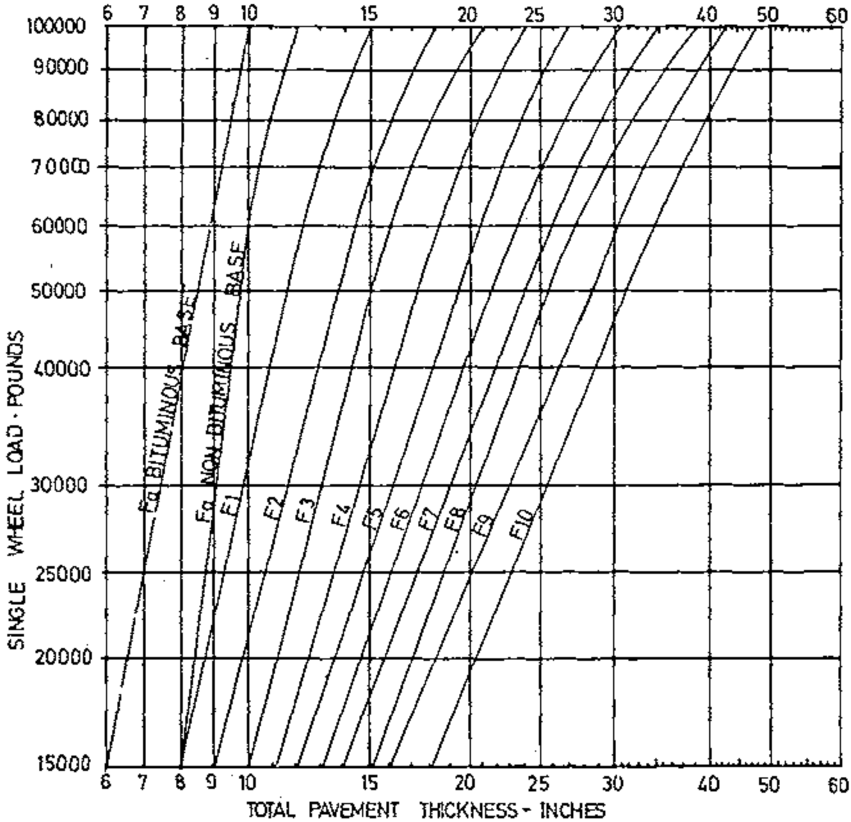
DESIGN CURVES FOR FLEXIBLE PAVEMENTS—TAXIWAYS, APRONS, AND RUNWAY ENDS

Fig. 1.

Note:
1. Fa curves represent combined thickness of surface and base courses.
2. No subbase required on Fa subgrades.
3. Horizontal increment, at design wheel load, between a particular subgrade curve and Fa curve represents the subbase thickness required.

formance, prevent the entry of water and to maintain the desired subgrade properties. The generally selected thickness of surfacing for an airfield pavement lies between 3 and ½ in of bituminous macadam. RESPB No 5D[3] is a useful guide. There is a school of engineering thought which favours the "thin skin" surfacing method. It is held that providing the base course is strong enough, eg the right CBR has been achieved, then the surface need only be as thick as is necessary to prevent the ingress of water. This often results in the selection of a surfacing thickness of ½ in. MacDonald on Aerodrome Construction in Nigeria[4] describes the construction of laterite airfields which successfully used a thin surfacing, of the order of ½ in, on the grounds of cost limitations and construction speed requirements. In designing a pavement with a thin surface, due account has to be taken of the danger of capillary action and lateral percolation.

The use of the CAA method is shown by the design example in Appendix



DESIGN CURVES FOR FLEXIBLE PAVEMENTS—NONCRITICAL RUNWAY AREAS

Fig. 2.

Note:

1. Fa curves represent combined thickness of surface and base courses.
2. No subbase required on Fa subgrades.
3. Horizontal increment, at design wheel load, between a particular subgrade curve and Fa curve represents the subbase thickness required.

"A". The result, based on the same data, but using Fig. 22 from MPBW Technical Publication Number 109,[5] is also given in this Appendix. In using either design procedure, a careful and informed appreciation of the whole problem involved must be made by an officer with the qualifications appropriate to the scope of the project.

References

[1] Airfield Pavement Design by Lieut-Colonel J. H. Fyson, MBE, MC, published in the *RE Journal* of December 1962.

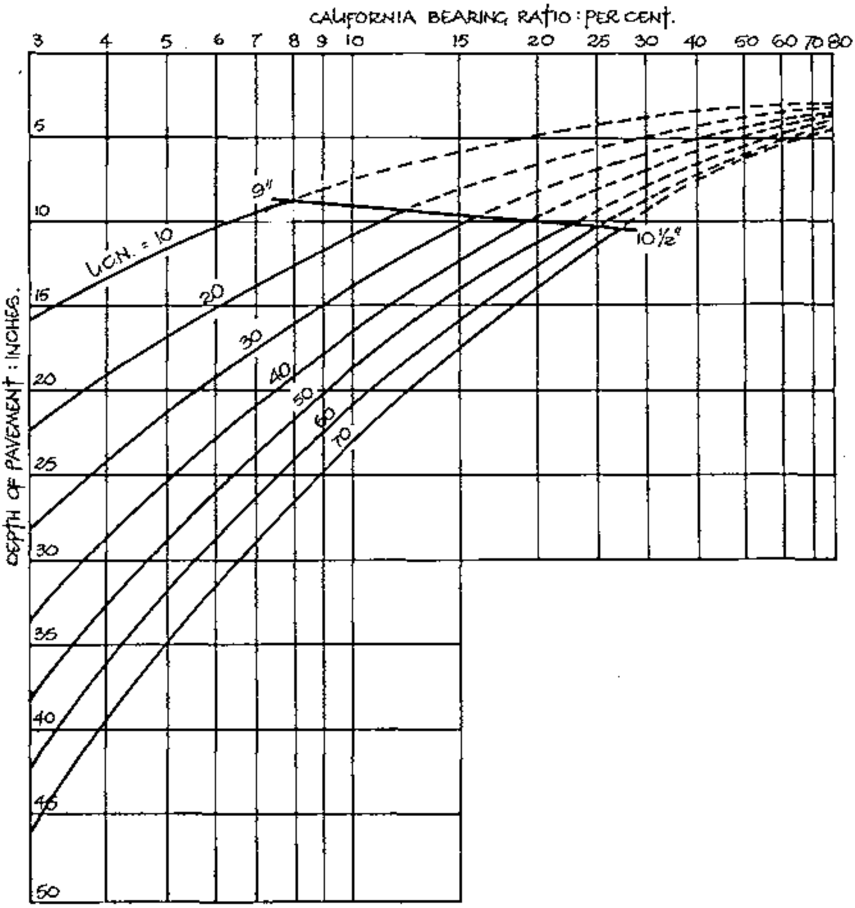
[2] Aerodrome Manual Part 4, published by the International Civil Aviation Organization.

[3] RESPB No 5D. Soil Mechanics. Section 33 para 1b (with amendment No 5/June 1959) and para 1d.

[4] Proceedings of the Institution of Civil Engineers 1953, Paper number 5884.

[5] Ministry of Public Buildings and Works Technical Publication 109—Airfield Design and Evaluation. Fig. 22.

[6] Military Engineering Volume Five. Roads and Airfields Part Two 1952 Fig. 4-7.



DESIGN CURVES FOR FLEXIBLE PAVEMENTS.

Fig. 3.

Appendix "A"

Airfield Pavement Design using the USA Civil Aeronautics Administration and the reversed Load Classification Number methods.

There is a requirement for an airfield to be built on a small island off the English coast capable of taking an MRT aircraft with an LCN of 20 (ESWL 20,000 lb). Tests show that the predominant soil is a yellowy brown fine sandy silt. A check classification gave the following Atterberg limits; liquid limit 40 per cent, plastic limit 25 per cent, plastic index 15 per cent. The sieve analysis showed that approximately 0–45 per cent of the material was retained on a No 10 sieve (American size). Note that a comparison of American and British Standard sieve sizes is given on page 87 of *Soil Mechanics for Road Engineers.*[6] The CBR found by separate tests was 8. Local records indicated that the ground was well drained but subject to appreciable frost action.

What is the design thickness required for taxiways, aprons and runway ends?

From Appendix "B" the soil is defined as type E5 and Fig. 1 indicates a subgrade class of F2. From Fig. 1 a subgrade class of F2 obtained from Table 2 subjected to an ESWL of 20,000 lb requires a total pavement thickness of 11 in.

From Fig. 3 with an LCN of 20 and CBR 8 the pavement thickness required is 13 in.

Appendix "B"

	Soil group	Mechanical Analysis: Material retained on No10 sieve percent *	Material finer than No10 sieve percent: Coarse sand passing No10 retained on No60	Fine sand passing No60 retained on No 270	Combined silt & clay passing No 270	Liquid limit	Plasticity index
Granular	E-1	0-45	40+	60−	15−	25−	6−
	E-2	0-45	15+	85−	25−	25−	6−
	E-3	0-45			25−	25−	6−
	E-4	0-45			35−	35−	10−
	E-5	0-45			45−	40−	15−
	E-6	0-55			45+	40−	10−
Fine grained	E-7	0-55			45+	50−	10-30
	E-8	0-55			45+	60−	15-40
	E-9	0-55			45+	40+	30−
	E-10	0-55			45+	70−	20-50
	E-11	0-55			45+	80−	30+
	E-12	0-55			45+	80+	----
	E-13	Muck & peat — field examination					

TABLE 1 CLASSIFICATION OF SOILS FOR AIRPORT PAVEMENT CONSTRUCTION

* If percentage of material retained on the No. 10 sieve exceeds that shown, the classification may be raised provided such material is sound and fairly well graded.

TABLE 2 AIRFORT PAVING SUBGRADE CLASSIFICATION

Soil group	Subgrade class: Good drainage: No frost	Good drainage: Severe frost	Poor drainage: No frost	Poor drainage: Severe frost
E-1	Fa or Ra	Fa or Ra	Fa or Ra	Fa or Ra
E-2	Fa or Ra	Fa or Ra	F1 or Ra	F2 or Ra
E-3	F1 or Ra	F1 or Ra	F2 or Ra	F2 or Ra
E-4	F1 or Ra	F1 or Ra	F2 or Rb	F3 or Rb
E-5	F1 or Rb	F2 or Rb	F3 or Rb	F4 or Rb
E-6	F2 or Rb	F3 or Rb	F4 or Rb	F5 or Rc
E-7	F3 or Rb	F4 or Rb	F5 or Rb	F6 or Rc
E-8	F4 or Rc	F5 or Rc	F6 or Rc	F7 or Rd
E-9	F5 or Rc	F6 or Rc	F7 or Rc	F8 or Rd
E-10	F5 or Rc	F6 or Rc	F7 or Rc	F8 or Rd
E-11	F6 or Rd	F7 or Rd	F8 or Rd	F9 or Re
E-12	F7 or Re	F8 or Re	F9 or Re	F10 or Re

E-13 Not suitable for subgrade

The Part Played by the Royal Engineers in the Development of Ghana

By Colonel W. G. A. Lawrie, MA, AMICE
Defence Adviser, Accra (1964–1966)

The development of the Gold Coast and its emergence as the independent state of Ghana have followed the traditional pattern of many a British Colony —exploration, trade, trouble with the natives, fruitless appeal to the home government, failure of locally mounted operations, Expeditionary Force from Britain, annexation of Colony. The subsequent opening up of the country and the spread of education led to political consciousness and a demand for independence. The last few years have seen heavy and recklessly unwise spending on all kinds of development and prestige projects, but in spite of Ghana's current balance of payment difficulties it is impossible to avoid the impression that Accra is a boom town. Grandiose hotels, offices and public buildings are shooting up and the town is full of cheerful, well-fed, busy people. The *per-capita* income is one of the highest in Africa.

Driving out of the town past the international airport with Ghana Airways VC 10s on the tarmac, and along the new motorway through the industrial area to the modern port of Tema, it is hard to realize that there are many elderly Ghanaians who remember the events of 1900. That was the year when Sir Frederick Hodgson, the Governor of the Gold Coast, and Lady Hodgson, were besieged in the fort at Kumasi by the Ashanti armies and only escaped after two months of terrible privations by creeping out in the early morning mist past piles of mutilated corpses and picking their way to the coast, down a muddy footpath through swamps and jungles protected by a small body of loyal troops.

The dramatic and sensational changes which have taken place in the last sixty-six years have been made possible to a remarkable extent by the efforts of the Royal Engineers. In spite of difficulties of climate and terrain, small groups of officers and men evolved some sort of order out of chaos, firstly in helping to pacify the Ashantis, then in developing communications, and finally in training the engineers of the Ghana army for employment on useful civil engineering projects. The state in which Ghana would have been today without their work is evident when flying over the bulge of West Africa from Dakar to Accra. For hour after hour there is nothing to be seen but dense tropical forest. Suddenly on reaching the frontier of Ghana there are clearings and houses and a reasonable network of roads and railways. The contrast is very striking.

A former Governor of the Gold Coast when asked to recommend what equipment an officer should bring out from England put a coffin at the head of the list, but in spite of the evil reputation of this part of the world many retired RE officers who served in the Gold Coast more than forty years ago are not only still hale and hearty but describe those early days as some of the happiest times in their careers. This article is the result of piecing together their stories, and accounts from old books and reports now housed in the National Archives of Ghana. It may help to put in perspective the recent phase of attacking "Colonialist" regimes and belittling their efforts, not to mention the senseless gesture of breaking off diplomatic relations with Britain in December 1965, which in fact precipitated the downfall of Nkrumah.

Between the fifteenth and eighteenth centuries, Portuguese, Dutch, Swedish, Danish, Prussian and British traders established posts along the west coast of Africa. These merchants were on more or less friendly terms with the tribes living in the coastal areas but were forced to build a series of strongholds to defend themselves against rival Europeans as well as against the warlike Ashantis who lived further inland. There are still forty-three forts in various states of preservation in some 300 miles of Ghana's coastline. During the eighteenth century the British gradually consolidated their position. From 1807 to 1867 the Royal Navy patrolled the seas off West Africa in an attempt to intercept slave ships, but it was not until 1872 that the whole of the Gold Coast came under British control. Since the beginning of the nineteenth century the British Headquarters had been at Cape Coast, about 140 miles due south of Kumasi, but separated from it by steaming tropical forests, swamps and rivers, particularly the River Pra, which was halfway between the two places and marked the boundary of the Ashanti kingdom. Native footpaths, in many cases only nine inches wide, led from village to village. At that time diseases such as smallpox were prevalent and there were no prophylactics against the persistent attacks of malaria which prostrated all Europeans in turn.

There were no British troops in the Colony and the British government were reluctant to send white men to such a notoriously unhealthy part of the world. Punitive expeditions against the Ashantis were mounted with local levies and West Indian regiments in 1824 and 1863 but both were complete fiascos, mainly owing to the absence of engineer support. Heavy rain turned the existing jungle paths into quagmires through which troops had to wade, sometimes up to their chests in water. There was no animal transport and everything had to be carried by native porters who required feeding, doctoring and protection from attack. There was no shelter from tropical downpours for troops, rations or ammunition. In 1824 the Governor's head complete with cocked hat and ostrich feathers was carried back in triumph to Kumasi, and in 1863 the expedition withdrew in disorder without a shot being fired. When they got to the Pra, 200 ft wide between steep banks covered with dense undergrowth, they found only one dugout canoe available to ferry the army across. Before more could be brought up the gunpowder was soaked through and the men incapacitated by fever and dysentery.

When it was decided to teach the Ashantis a lesson in 1873 no efforts were spared to make the operation a success. A brilliant young officer, Colonel Garnet Wolseley, with revolutionary theories on the conduct of war, was appointed to command the force. Major R. Home, RE was selected as CRE nine months beforehand. He spent three months studying all the information he could find about the Gold Coast, which he said afterwards was very limited and mostly inaccurate, but it was sufficient to enable him to make a sound engineer plan. When this had been approved by the Commander he prepared his engineer orbat and stores list and actually set sail from Liverpool with his staff and all his stores three months before hostilities were due to commence.

During the planning stages in London it soon became clear that the difficulty would be to get an army into the interior of a country completely devoid of roads or means of subsistence. Once fit British troops could be brought face to face with the Ashantis the campaign would be over. It was essentially an engineer problem to move the army quickly through very difficult and unhealthy country and to provide adequate accommodation for troops, stores and hospitals. The plan was to clear a road wide enough for infantry in fours through the friendly country between Cape Coast and the River Pra before the arrival of the main body. As far as possible local labour, tools and materials were to be used. A base depot was to be built at Cape Coast and a forward base at Prasu with intermediate staging posts every 10 miles. A timber bridge on crib piers was designed at Chatham for the Pra crossing. The main item of stores to be shipped out was hutting, which was carefully—"put together in bundles in London (all the corresponding pieces of one hut being put up together and hooped with hoop iron, certain spare bits being introduced) each hut being numbered and lettered and the nails, locks, bolts etc with tools for putting the huts together, being all carefully put up in separate boxes". (Is this the first example of properly designed parcelling?) Those who have served in West Africa will not be surprised to learn that the CRE had to erect the first hut with his own hands before the local labour could manage it. Proposals to take railway and telegraph stores were turned down but they did take a "Steam Sapper" which could not move on such roads as there were and finished up sawing timber in the RE yard at the base.

General Wolseley and his staff, including the CRE, landed at Cape Coast on 2 October 1873. The provision of British troops had always been subject to confirmation, although Wolseley had never had any doubt that they would be required, and he soon decided to ask for a complete Brigade to be sent out. The CRE realized that native labour was weak, timid and unused to tools, and sent back at once for 28 Field Company and a telegraph detachment RE. Before they arrived early in December the native labour force amounting to 1,370 men under a handful of sapper officers had got the road through to the River Pra and had constructed seven intermediate fortified camps. The field company started building the advanced base at Prasu and a trussed girder bridge over the river Pra on 18 December, using some Blanchard pontoons which, though obsolete, proved most useful. On 1 January 1874 the Rifle Brigade, Royal Welch Fusiliers and Black Watch disembarked at Cape Coast and set off for the front. The bridge was completed on 5 January and the sappers moved on across the Pra into hostile country where the native labour force was too frightened to work.

As the jungle was so thick the sappers had no covering party and suffered a number of casualties, including one of their best officers, Captain Buckle, who was killed at Amoafo on 31 January. It was not uncommon for them to be fired on by both sides. For his part in the action at the village of Ordahsne, close to Kumasi, Lieutenant (later Colonel) M. S. Bell, RE was awarded the

Victoria Cross. The announcement of the award in the *London Gazette*, carried the following citation: "*For his distinguished bravery and zealous, resolute and self-devoted conduct at the Battle of Ordahsne on 4 February 1874, whilst serving under the orders of Colonel McLeod, KCB, of the 42nd Regiment who commanded the advance guard. This Officer's fearless and resolute bearing, being always in the front, urging on and encouraging an unarmed working party of Fantee labourers to clear an area whilst exposed to the fire of the enemy from the front and rear, contributed very materially to the success of the day. By his example he made these men do what no European party was ever required to do in warfare, namely, to work under fire in the face of the enemy without a covering party.*" Eventually, led by the Black Watch the troops fought their way into Kumasi, and the same day the telegraph was open to Cape Coast. The sappers blew up the Palace, fired the town and at once set off back to the coast, leading the way so that they could repair the road and bridges before the main body passed over. 28 Field Company re-embarked on 15 February after a model campaign of just over six weeks, but they left behind them a route to Kumasi which was not only used in subsequent campaigns but has now been made into a fast motor road.

However this was no way to impose a lasting political settlement. Chaos and anarchy in the corrupt and bloodthirsty Ashanti kingdom were hindering trade, and in 1890 the British government offered to take Ashanti into the Gold Coast Protectorate. When negotiations broke down another British expedition was mounted from Cape Coast in 1895. This time Major H. M. Sinclair was appointed CRE with a small staff and thirty RE NCOs to control a native labour force. A telegraph detachment was again sent out and found they could use the same insulators still on the trees since the 1874 campaign. Some lessons from the previous occasion had been learnt—a covering force was provided in front of the sapper parties consisting of Hausas under the command of Major R. Baden Powell, later to become the Chief Scout, whose original manuscript war diary illustrated with beautiful pen and ink and water colour sketches is still in Accra. A floating bridge was built over the Pra; accommodation, water supply and improvement of tracks were carried out, but not a shot was fired. The campaign was later described as shadow-boxing. The British troops landed at the end of December and entered Kumasi on 17 January 1896. The Asantehene, King Prempeh I, surrendered and was exiled to the Seychelles for twenty-eight years. His immediate successor, Prempeh II, is still Asantehene and complained to me the other day that we had been very hard on his uncle. The troops were back in England again in February, the speed of the campaign being again a proof of the efficiency of the sappers' work, but once more no lasting settlement had been achieved.

This was the last time that Royal Engineers took part in operations in the Gold Coast. From now on they concentrated on civil works. Immediately after the 1896 campaign Lieutenant McInnes, RE was sent up to Kumasi to build the fort, which is still standing in the middle of a modern shopping centre and now houses the Ghana Army Museum. Captain J. I. Lang, RE carried out railway surveys which resulted in a railway being opened in 1898 between the goldmines at Tarkwa and the nearest port at Sekondi.

The episode of 1900 when the Governor was besieged in Kumasi Fort required another expedition to relieve him but this time no sappers could be spared as they were all otherwise engaged in the Boer War.

A very important individual in the history of the Gold Coast was Captain Sir Montagu Ommaney, GCMG, KCB, ISO, RE. He was the first recipient of the Fowke Medal at the SME and in 1872 designed the Royal Engineers Institution building at Chatham. In 1874 he joined the Colonial Office, where he was most insistent on the policy of developing roads and railways in the Colonies. In 1900 he became Permanent Under Secretary under Joseph Chamberlain, who initiated a more generous financial policy towards colonial development. Ommaney was largely instrumental in obtaining approval for the construction of roads and railways in the Gold Coast and other African colonies, and it was on his advice that RE officers were appointed as Governors, the first being Major M. Nathan, RE (1900–4) who had already completed a successful tour as acting Governor of Sierra Leone.

Arriving immediately after many years of fighting, culminating in the troubles of 1900, Nathan found plenty to do. In those days the Gold Coast, like other Colonies had to finance developments out of revenue, which in 1900 was only £330,000. Looking back on it this would seem to have been a misguided policy because the revenue depended entirely on the development of natural resources and the improvement of communications to bring them to market. He found that the only means of transport was by head porterage along narrow tracks through the forests. There was not a single motor vehicle, nor was there a harbour. The railway had only progressed a few miles beyond Sekondi. But perhaps the most urgent problem was created by the absence of maps. Concessions had been granted to mining companies who were keen to exploit the country's mineral resources but there were no maps on which the limits of their allocations could be plotted. Captain A. E. G. Watherston, RE was appointed Director of Survey, and RE survey teams began to work on the frontiers and mining areas. Among them was Captain F. G. Guggisberg, RE who began his long association with the colony in 1902.

Boundaries of mining concessions were generally surveyed with 5-in micro-theodolites and steel tapes. In order to provide a framework, the department surveyed a number of traverses along the main roads and paths, putting in small concrete pillars at intervals. These were surveyed with 5-in micro-theodolites and steel tapes. Azimuths were observed at intervals, and bearings adjusted between azimuths, while astronomical observations for latitude were taken at intervals of about 60 miles and co-ordinates adjusted between the latitude stations.

Longitudes were based on one observed at Accra by Captain Guggisberg by means of Greenwich time signals received by cable from Cape Town. Guggisberg also produced a map of the colony south of 7 degrees north in thirty-five sheets on a scale of 1/125,000. This map was partly compiled from compass sketches and rough surveys carried out by travellers and mining engineers, as well as from the department's own surveys. It showed the main roads and paths, the railway, main towns and villages and hunters' trails. Rivers and streams were shown in blue and hill features were roughly indicated by brown shading. No surveys of any kind existed for large stretches of the country and over many of these appeared the words "Fetish Forest".

Spurred on by Nathan's enthusiasm the railway was pushed through to Kumasi by 1903. He had been knighted in 1902 but was passed over for promotion to Lieut-Colonel because it was thought wrong for the Governor of a Colony to be examined by officers who happened to be senior to him in the Corps. However he was given a brevet and appointed Governor of Hong

Kong in 1904. Before then he had had time to move the Governor's residence into Christiansborg Castle, where the Queen and the Duke of Edinburgh stayed in 1961 and to get the Accra Polo Club going. He also initiated a survey for a new railway line from Accra to Kumasi, and by importing the first car to be seen in the colony, a Gardner-Serpollet paraffin-fired steam-driven vehicle, forced action to be taken about roads. But his most beneficial work was in stimulating the cocoa trade. In 1891 it is recorded that 80 lb of cocoa were exported. By 1900 this had risen to 500 tons, which jumped to 5,000 tons by 1904 and it was clear that this could lead to great things in the future. He left another sapper, Major W. E. Lees, as Director of the PWD who remained in that position until 1910, by which time motor roads had been built from Accra to Ayimensa and Dodowa about 20 miles away to facilitate the transport of cocoa and oil from the interior to the sea.

Watherston was appointed Chief Commissioner of the Northern Territories in 1905 and died there in 1909. Guggisberg was Director of Survey from 1905 to 1908, a period which he described in a fascinating book *We two in West Africa*. On his return to Chatham he was awarded the CMG. The RE connexion was continued by the formation of the Ashanti and Northern Territories Roads Department in 1909 under Major G. A. Leslie, RE which completed 61 miles of a road from Kumasi to Tamale before the outbreak of war. At the same time Lieutenant J. G. Hearson, RE was Superintendent of Roads in the Gold Coast.

In 1908 a new Survey Department was formed under Captain P. J. Mackesy, RE as Director of Surveys and Captain H. A. Lewis-Hall, RE as Deputy Director with some RE officers and NCOs as surveyors. Until it was closed down in 1914 it surveyed some 150 concessions and produced large scale plans of ten towns. It also completed 700 miles of theodolite traverse, 600 miles of spirit levels, and in 1911 commenced a topographical survey of the Northern Territories which resulted in a survey of some 10,000 square miles of country and the production of three map sheets on the 1/250,000 scale.

Development was limited by the revenue of the Colony which even in 1913 amounted to only £1.3 million, corresponding to a cocoa export of 52,000 tons. The people of the cocoa belt were determined to avail themselves of motor transport, but their vigorous efforts were very often misguided. In 1908 the PWD began the systematic replacement of wooden bridges by concrete and steel but in 1914 all British civil and military engineers were recalled to Europe and organized development came to a standstill. Administration was carried on by a greatly reduced staff, but chiefs and people vied with each other in subscribing to war funds and doing all in their power to uphold the British cause.

The Gold Coast Regiment took part in campaigns in Togoland, the Cameroons and East Africa between 1914 and 1918 but there is no record of any RE personnel or engineer troops in the order of battle. However, Captain J. P. F. Butler, commanding the Gold Coast Pioneer Company, won the VC and DSO in the Cameroons before being killed in Tanganyika in 1916.

In a speech in Parliament in 1956 Nkrumah gave Sir Gordon Guggisberg pride of place among "the many British officials who devoted their lives to the service of Africa", and it is true to say that Ghana's progress in every field owes more to him than to any other individual. His six years in the Survey Department gave him a detailed knowledge of the whole country and the problems facing each region. When he returned as Governor in 1919 he devoted his energy and determination to a far-reaching programme of development. He believed that education was the keystone of progress, and it was primarily to finance his educational schemes that he set about increasing the wealth of the country. He realized that Ghana's great natural resources were largely untapped owing to lack of communications. During the war years production of cocoa had improved by leaps and bounds and far outstripped available transport facilities. Farmers and merchants were clamouring for better roads and railways. But there were also urgent demands for hospitals, sanitation, water supply, schools, post offices, telephones and accommodation. So careful planning and accurate estimating was required to make the best use of the funds available. Guggisberg naturally turned to the Corps for assistance. It was decided to re-open the Survey Department in 1919 and proceed with a topographical survey of the country. Major H. A. Lewis-Hall, RE was appointed Director of Surveys and the first two members of the party, G. Cheetham and C. G. Woolner, started a rapid topographical triangulation in May 1920. Other RE officers were: R. L. Brown, E. R. L. Peake, B. D. Peake, W. H. Treays, D. M. Eley, R. R. Gillespie, E. E. Reed, R. P. G. Anderson, R. A. Milne and H. S. Francis.

In more or less open country topography could be supplied by plane table in the orthodox way but the greater part of the work was in country covered with dense tropical forest. Here the detail was supplied by compass traverses along the main roads and paths, with rope and sound traverses along the less important ones and along lines specially cut in the bush. The main compass traverses were tied in to the main trig or theodolite traverse framework. Heights were determined by aneroid runs adjusted between bench marks of known elevation, and rough contours interpolated.

Between 1920 and 1925 when funds became exhausted the special topographical party had surveyed some 40,000 square miles on the 1/62,500 scale. Later on, some of the officers serving with this party were employed on International Boundary Surveys on the Western and Eastern frontiers of the Colony. Other parties were:—

1. Special Framework Party, formed at the end of 1923 to undertake the survey of a rigorous framework. (E. B. Elkington, A. C. Shortt, F. B. Baines-Hewitt, H. Wace.)

2. A Wireless, or Astro-Radio Party to supply a rapidly executed framework for a small scale topographical survey of the Northern Territories. (F. Phipps.) (1924–8.)

3. A Forest Reserves Boundary Survey Party to undertake the survey of newly-formed Forest Reserves. (F. K. Stranack, E. R. Green, S. H. Cave.) (1924–31.)

4. A Special Town Survey Party to accelerate the production of large scale surveys of the main towns. (F. O. Metford.) (1928–31.)

Some idea of the difficulties of working in this sort of country may be obtained from the following extracts from letters I have received from officers who served in the Gold Coast Survey Department:—

"The Bush, Jungle or Forest has to be seen to be believed. The immensity of it is staggering and when you are in the heart of it you can see nothing more than 50 yards or so away. Even daylight is to a large extent blotted out. When looking for a mountain you may easily pass within a few hundred yards of its base without knowing it.

Specially difficult are those cases when rays have to be cleared in the direction of other Trig Points. Here the expert axeman comes into his own. He loves a big tree—it is an exciting challenge. One such turned out to be a mighty cottonwood with flying buttresses, which took 24 carriers to encircle as they stood facing inward with arms outstretched and hands touching.

The rainfall at the height of the wet season was prodigious. I remember one morning when 4 inches of rain fell in one hour. It was the nearest thing to raining 'stair-rods' I have ever seen. Honourable mention should be made of the voracity of white ants, the ferocity of driver ants and the persistence of the pestilential sandfly." *Colonel E. B. Elkington, FRICS.*

"There were elephant, lion and bush cow then in the Northern Territories. Sometimes we heard a lion roar when we were sleeping outside under mosquito nets, which somehow or other seemed to give one a feeling of protection." *Lieut-Colonel R. A. Milne, ACIS.*

"One Sheet I was given to survey had only a dotted line diagonally across it entitled—

'Macdonald's Route, 1904' (or something like that)

with a few names of villages scattered along it, each with a '?' after it. The blank spaces said 'Dense forest with heavy swamps'. Actually it turned out to be bone dry and rather hilly.

Another hazard was Ju-Ju. I remember one of my surveyors having a lot of trouble establishing a beacon on Krobo mountain. Every time he put it up someone tore it down again, presumably because it was a sacred place of the Krobo. But we won in the end.

From the maps produced road and railway engineers could at least know where the main valleys and ranges were instead of wasting months poking about blindly in the dense forest." *Major-General C. G. Woolner, CB, MC.*

Being dissatisfied with the way roads were being located by the PWD, Guggisberg set up in 1924 a Temporary Roads Department under Captain R. L. Brown, RE composed entirely of RE Officers and NCOs. In seven years they surveyed some 600 miles of roads in the Central Province and built about 300 miles, until the work was brought to an end in 1931 by a world slump in cocoa prices. Captain H. C. L. Bogle described the original methods used in a series of articles in the *RE Journal* commencing in September 1933.

RE officers were also concerned at this time with the work of the PWD in building hospitals and public buildings, improving sanitation and water supply and introducing electric light and telephone systems.

In 1927, when he relinquished his appointment as Governor, Guggisberg was able to report that during his term of office motorable roads had increased from 1,300 miles to 4,688 and railways from 269 miles to 475. He calculated that by spending £6.8 million on roads and railways alone he had brought about increases in the annual values of trade and revenue of some £13 million and £2.6 million respectively. Apart from the financial benefits the opening up of road and rail transport freed many thousands of men, women and girls from the old system of head porterage and released them for other work.

But it was useless improving the internal communications without providing an outlet. It had always been his dream since surveying the area in 1902, to construct a deep sea harbour at Takoradi, which had been originally recommended by British consultants in 1895. He engaged British engineers to design Takoradi harbour before he left England to come out as Governor, and work started little over a year later. The trade slump of 1922 and strikes in England delayed the completion date until after his departure, but the advantages which he foresaw would accrue to Ghana from the opening of Takoradi harbour can be gauged by the difference between the cargo handled at Sekondi in 1926, amounting to 317 tons per day and 6,200 tons handled daily at Takoradi in 1963.

One of Guggisberg's proudest achievements was the founding of Achimota College which he described as "the most important step ever taken by the Government to assist the progress of the people of the Gold Coast". This was required to produce suitable sixth form pupils to go on to the University of Ghana which has since been built not far from Achimota. The foundation stone was laid by the Prince of Wales in 1925 and it is still a flourishing Institution under a British headmaster with beautiful grounds and playing fields.

On the political side it was during his Governorship that a new Constitution came into force granting electoral representation on the Legislative Council for the first time to the people of Ghana (April 1925). Provincial Councils of paramount chiefs were formed based on the institutions which the people of Ghana found best suited to them and which he preferred to "mushroom constitutions based on the ballot box and the eloquence of politicians over whom the people have no control".

Before leaving Ghana he prepared an outline budget for the year 1936–7 forecasting the increase in revenue which would have been brought about by the various schemes he had introduced and showing that the increase in expenditure would still leave a comfortable surplus. He left confident in the soundness of Ghana's financial position. A confidence which was amply justified by events up to the time of Ghana's Independence in 1957.

In 1919 many men who had served in the Royal Engineers during the war came out to the Gold Coast to resume their former jobs or to take up new appointments. Due to their keenness volunteer Engineer units were gradually built up. As a result when war broke out again in 1939 the Gold Coast Field Company was quickly raised and brought up to strength. The British personnel were mainly mining engineers and geologists from the diamond mines at Akwatia and the Africans were either from the mines or locally recruited artisans. As time went on young RE officers from OCTUs in England were posted in.

The role of the Royal Engineers serving with Gold Coast troops during the 1939–45 war was to provide Officers and NCOs to back up the West African Engineers and assist in the raising and training of units which took part in campaigns in East Africa and Burma. In June 1940 the Gold Coast Field Company, re-named 52 (West African) Field Company, under command of Major J. S. Thain, MC from the Gold Coast PWD embarked for East Africa as part of the 11th (West African) Division, where it fought with distinction throughout the Abyssinian Campaign, being employed on traditional sapper tasks of building roads and defences and providing water, but also frequently fighting as infantry.

In November 1941 the unit returned to Accra and became 2 (WA) Field Company. In May 1942 they were sent to Gambia with the 2nd Gold Coast Brigade as a threat to Vichy French forces in Dakar. After eight months they returned to the Gold Coast and were employed on improving the roads through Nigeria, Dahomey, Togo and up to Ouagadougou to enable French Colonial Forces to move up to take part in the North African campaign. After a period of intensive training in jungle warfare the company was posted to Nigeria in September 1943 to join the 82nd (WA) Division along with 9 (WA) Field Park Company, another Gold Coast unit.

In the meantime 5 (WA) Field Company had been raised in the Gold Coast and joined the 81st (WA) Division whose CRE was Lieut-Colonel W. W. Boggs, RE. The Division moved into Burma in November 1943, under the command of Major-General C. G. Woolner, who had served in the Gold Coast Survey in the 1920s. 5 (WA) Field Company took part in the advances to Kyauktaw in 1944 and Myohaung in 1945 which were on a head load and air supply basis. The sappers performed prodigious feats in hacking jeep tracks out of dense mountainous jungle with only hand tools, preparing air strips for the evacuation of casualties, and carrying out many FBE and assault boat river crossings.

2 (WA) Field Company and 9 (WA) Field Park Company embarked at Lagos in April 1944 and reached Burma in October. They took part in 82nd (WA) Division's advance down the Kalapanzin Valley at the end of 1944 and reached Taungup in May 1945. The Sappers were usually in the lead hacking a track through dense bamboo forests, building or strengthening bridges as they went. They worked long hours through intermittent rain, frequently spending days without getting dry. Leeches were numerous and latterly scrub typhus.

Lieut-Colonel (later Brigadier) R. P. E. Stoney, who was CRE 82nd (WA) Division, writes that in the divisional engineers the company commanders were mainly "coasters", i.e. WAE rather than RE, platoon commanders were from Rhodesia or South Africa given temporary RE commissions, backed up by young officers from RE OCTUs in the UK. "All that came to Burma with 82 Div were first class and made first rate teams, bound together in a common high regard for the Gold Coast and Nigerian soldiers, their cheerfulness, stoicism and amazing capacity for work." In December 1945 the Divisional Engineers moved down to Lower Burma re-commissioning the 110 mile Taungup-Prome road after the monsoon and eventually sailed for home in June 1946. Extracts from HQ RE 82nd (WA) Division's farewell circular letter will revive memories of those who were then serving—

"Aitchkewary (1943) Ltd.,
Incorporating ENSEC (1944) Ltd.,
Mental Hospital,
Kokine Rd.,
Rangoon.

29 June 46

Dear Sir or Madam,

You will no doubt have seen in the local press that the old-established firm of 'AITCHKEWARY (1943) Ltd." went into voluntary liquidation on 28 June 46, by a happy coincidence the Managing Director's 43rd birthday, enabling him to adopt a similar state.

To all our customers and friends—not always synonymous terms—the time has come to say goodbye, with thanks for past favours and best wishes for the future, if any.

You will be glad to know that your interests will be handled in future by one of our subsidiary companies—Messrs Wardrop, Lyle & Co. This company was founded in 1940, joining AITCHKEWARY at the time of the great merger in 1943. With their long experience you may rest assured that any orders placed upon them will be expeditiously effected in strict rotation, subject only of course to the local bribery and corruption rules.

Having made such provision for the future your Directors feel that a brief recapitulation of the past trading of AITCHKEWARY and its subsidiaries might be of interest to our newer customers.

At the end of 1944 our parent concern decided to open up a vast new network of interests in the hitherto unexplored ARAKAN, where a major boom was confidently expected and on several occasions experienced. This brought a lot of work to your company particularly in the fields of road construction, drainage and sewage disposal. Never before in the whole history of man have so many laboured for so long for so little. More recently in spite of dwindling staff, the main office has been overhauled, unnecessary records burnt, and a third press button marked 'STOP' added to the original 'SLOW' and 'DEAD SLOW' buttons on the Managing Director's desk.

And so with the exotic music of the great crested shite-hawk still drumming in our ears, we say goodbye to Sunny Burma, Land of the Great Image, mysterious, glamorous, exotic, fragrantly scented and bloody wet.

R. P. E. Stoney, Lt Col
CRE 82 (WA) Div"

As a result of these operations the Gold Coast sappers under their RE officers developed a tradition of being able to get a road through any country under any conditions and of being able to cross any river with the minimum of equipment. The climate and terrain of Burma were so much worse than West Africa, that the Ghana Engineers are still undaunted by any tasks given them in opening up communications in peace time.

When the 81st and 82nd (WA) Divisions returned home for demobilization it was decided to retain one regular field company in the Gold Coast, formed from soldiers with unexpired service. This became known as 35 Field Squadron GCE which was raised on a special establishment including an enlarged HQ troop to hold the skilled tradesmen who would form the nucleus of a Field Park Squadron if it should be required. Major R. A. Woodfield, RE was the first post-war OC (1946–8) followed by H. W. Baldwin (1948–9), J. L. Raikes (1949–52) and G. W. Cole (1953–6).

After the war the Squadron settled down to normal garrison life with its British Officers and NCOs, but the African NCOs, due to their Burma experience, proved so capable that in September 1955 the Squadron was the first unit of the Ghana Army to release all the British NCOs.

It has always been the declared policy of the Ghana Government to make full use of the Army to assist in the development of the country. In practice the Sappers are the only people who can do this effectively, and, even before Independence, the Squadron was employed on social welfare projects, particularly in out of the way parts of the country. Major P. E. G. Carter, MBE, RE, who commanded the unit from 1956–9, describes many ambitious schemes for building roads and bridges during this period. His NCOs, now commissioned, continue on the same lines. Major D. N. Wright, RE, who took over from him, had the unusual experience of taking the Squadron to the Congo, with four other RE officers, when the unit was deployed as an Infantry Battalion with the United Nations in 1960 and 1961. They did excellent work in keeping the peace and helping starving civilians, but also in training the Sappers to operate in difficult circumstances. Major Wright reports that their morale remained very high throughout this period and their self discipline was remarkable. Shortly after the Squadron returned from the Congo it was decided that no British officers would remain in command of Ghanaian troops, but the African NCOs rose to the occasion nobly and the Sappers are still some of the best troops in the Ghana Army and keen to retain their links with the Royal Engineers.

Ever since 1940 there has been a RE Works Services section in Ghana. During the war they took on many crash programmes for accommodating troops but probably the only permanent effect on Ghana was the work of Major E. Maxwell-Fry, FRIBA, RE, who was GE Accra until 1944. After leaving the army he was seconded to the staff of the Resident Minister, Lord Swinton, as Town Planning Adviser for the four British colonies in West Africa. He prepared master plans for Accra, Kumasi, Takoradi and other places and finally wrote a book called *Village Planning in the Tropics* as a guide to district officers, which is still in use.

He also undertook a very large programme in the construction of secondary schools and teacher training colleges, which were to form the necessary basis for an attack on mass education, and which were built over a period of nearly fifteen years. As a result of this work, which started many years before Independence, Ghana is better equipped with schools than any other African country of its size. Touring the country today one is continually struck by the high standard of school buildings, even in quite remote places, both from the point of view of appearance and suitability. Guggisberg would have been delighted to know that another sapper officer had such a hand in fulfilling his pet scheme.

The Works Service Engineers of the Ghana Armed Forces are still mainly staffed by RE officers and NCOs, although the numbers are dwindling as Ghanaians are trained to take their places. RE officers have recently had the unusual experience of co-operating with a Yugoslav Admiral over the construction of a naval base and Russian and Czech engineers engaged on building an airfield and a Small Arms factory.

It is interesting to note that General Sir Frank Simpson, the Chief Royal Engineer, was until recently Chairman of the West Africa Committee, an organization which exists to promote trade between Britain, Ghana and other West Africa countries—the modern counterpart of the Royal Africa Company founded by Charles II in 1672. So the pendulum has swung full circle.

Today Ghana is free and independent, and under the new regime anxious to recognize the debt she owes to her former masters. Now is a good time to place on record the efforts of the Royal Engineers in peace and war in bringing her to this stage—men who did not spare themselves, inspired perhaps by the spirit of Guggisberg's words—

"And I shall ever pray that God's blessing may rest on the work you do for the loyal subjects of His Majesty in this great little country."

My Dogs Wear My Collars

By Colonel R. B. Oram, OBE, ERD

In 1595 the Spaniards had fortified the Brittany ports of Morlaix and Quimper. Young Sir Nicholas Clifford, who had fought with the English contingent, came back to court wearing a medal given him by Henri IV. When Queen Elizabeth spotted it she ordered him to return it at once, adding the angry reprimand, "My dogs wear my collars". The impression the incident made has hardened into immutable custom. Recently an ex-Prime Minister admitted to having an Order of Chastity, presented to him by a North African monarch, but which this sixteenth-century mandate prevented his wearing.

Fortunately the Serbian Silver Medal for Gallantry, presented to me early in 1919, brought with it the Military Secretary's permission to wear the appropriate ribbon on my service dress. In the mysterious ways of the War Office it had all begun two years before. I had served in France with a London Territorial Regiment as a company bomber until in 1916 a German stick bomb sent me home to finish the war as a soldier clerk in the War Office. The establishment side one day demanded to know in how many places I had been wounded. I casually answered—it was a rough estimate—"thirty seven" and this figure was duly entered in the correct column of the form. Afterwards I learnt that my only competitor, who had been shot through one lung, rang up the paltry score of two so I led the field by thirty-five.

By 1919 I had consigned this report, with others of like triviality, to a place under the office carpet; perhaps, I thought, some wise civil servant has sent it, in a double envelope, to the OC Troops, Tristan-da-Cunha, the grave of all unwanted papers. However, three days before I was due to be demobilized, the Director of Movements, a Brigadier-General, sent for me. On his desk lay a gleaming silver medal, suspended from a length of deep red ribbon. In his hand was a letter from the Military Secretary's office. "I have been ordered to give you this medal, QMS Oram. I don't know what it is and I don't expect you do either. You can have it now or, if you prefer, you can be decorated on a parade at Wellington Barracks. Which would you like?" I was quite ready, at that stage of the war, to take the cash and let the credit go and he handed me the medal with a smile and a congratulation. I wondered how the red ribbon of my new order would look, flanking Pip, Squeak and Wilfred with the MSM. I knew that I should have to contend with the natural curiosity of the other soldiers in Whitehall and I consulted Spinks in Piccadilly immediately. The elderly assistant took my medal into the back regions to get it identified; it had beaten him. Returning, he asked if he might offer his sincere congratulations. I told him that before congratulating me he had better tell me what the medal was. "This," he said, "is the Serbian Silver Medal for Gallantry, a most unusual decoration. King Peter of Serbia rarely gives it to anyone outside his own army". Clutching a length of ribbon I walked back to the War Office where I protested that I could not wear a medal that I had done nothing to earn. The answer was simple and to the point. "His Majesty has been graciously pleased to sanction the award of this decoration; when you report for duty tomorrow morning you will wear the ribbon of this medal in the correct position. If you fail to do so you will be put under arrest for being improperly dressed."

Having still three days to serve I complied although I could feel every soldier's eye boring into my left breast.

Part of my demob leave was spent in the depths of Suffolk, where the locals knew little of the finer points of "Honours and Awards". To my acute embarrassment it was soon being put round that "the soldier staying up at the schoolhouse has got the Victoria Cross". It was idle to point out the colour of my foreign decoration was too deep for the VC. Neither would one expect to find the Empire's premier decoration slinking behind a clerical medal and a few service ribbons. As soon as my leave was over the tunic was discarded; for the next twenty years I hardly gave the medal a thought.

By 1938 I, with many others, again put on the King's uniform. This time it was as a captain in a Docks Operating Group of the Royal Engineers (SR). Before my brass buttons had lost their first shine I arrived at the peace-time camp at Longmoor, feeling very conscious of the new Sam Browne and my five medals all in their correct position. As I came off Apple Pie, after my first parade, a sergeant from the instructional staff stood in my way. "Beg pardon, Sir, but my mates and I were having a bit of an argument in the mess and we thought you could settle it for us."

"Well sergeant, and what was the argument about?"

"Sergeant Gorman, who reckons he knows all about medals said that the one you're wearing (there was no need to say which) was the French Croix-de-Guerre, but I said the ribbon was not right, so we thought that perhaps you'd tell us what it was."

Knowing only too well what the problem of an unidentified medal in their midst meant, I told him what it was, adding, "For your information, sergeant, I have never been to Serbia and I'm not particularly gallant." He dismissed the disclaimer and went off to collect his bet. And so the pattern repeated itself, with a few variations, during the next seven years, whenever I was posted to a new theatre. In 1945 I was returned to a then non-existent Supplementary Reserve.

In 1947 I again put on uniform, this time in command of a Port Operating Group, RE (SR). At our first camp at Marchwood, on Southampton Water, I was the guest of the Regular Sergeants' Mess. "Beg pardon Sir, we was having a bit of an argument last night about that ribbon you're wearing, etc." At each post-war camp I attended I found the interest was still there although my piece of Serbian ribbon was now flanked by the ribbons of the second war and Serbia, as a source of decorations, had long ceased to exist.

The War Office, in 1951, presented me with a second bar to my bowler hat, awarded back in 1919. With it went the privilege of no longer being subject to recall, so I took off my uniform for good. On Remembrance Day I fall in with my old colleagues, our freshly polished medals gleaming in the pale November sun. None is now interested enough to ask me about the medal I wear last in order.

The joke that started almost a lifetime ago would have died of inanition but for a talkative Yugoslav guide I met in Rijeka last summer. Thinking to make conversation I mentioned that King Peter of Serbia had given me a medal in the first war. "But you have been in my country before, fighting with our army and you have not told me and now you have a medal; you are a very brave man." He beamed on me and translated rapidly to the party. A little taken aback at his enthusiasm for a king that I thought everyone by now had forgotten, I explained as best I could, the wonderful ways of a War Office, that gave medals to absentee soldiers and paid a man five times as much for pushing a pen in Whitehall as he had received for exchanging bombs with the enemy in the front line. I'm afraid I made very little impression. "In my country we do not do things like that. It would not be allowed." He felt so strongly that the whole episode was an injustice to Serbia and that the only proper course open to me was to return it at once to Tito, that I had not the heart to tell him about Elizabeth and her dog collars.

Correspondence

Brigadier H. A. L. Shewell, OBE,
Rock Close,
Ashburton, Devon.
13 April 66

The Editor,
RE Journal

COMMON HERITAGE

Dear Sir,

In his interesting article in the March *Journal*, "Scamperdale" states, in passing, that whereas the Sappers have the reputation of being either "Mad, Married or Methodist", the Gunners are said to be "Poor, Pious or Proud".

I would like to register a mild note of interrogation about the second part of the quotation. As the Sapper son of a Gunner father who retired about the turn of the century and died in 1939, I have always heard the Gunners quoted as being "*Poor, Proud or Prejudiced*". This phrase, which compares better, both in rhythm and rhyme, with the "*Mad, Married or Methodist*" of the Sapper, was quoted by me some years ago, in a light-hearted speech at a wedding where the groom happened also to be the Sapper son of a Gunner father.

Afterwards, a lady came up to me, with tears in her eyes, and said she hadn't heard the expression for more years than she cared to count. She did not, however, accuse me of quoting it wrongly.

I feel, Sir, that the correct phraseology ought to be established while those able to recall ancient times can still do so. Perhaps some Gunner, of even older vintage than myself, could settle the question?

Yours faithfully,
H. A. L. Shewell.

Note by the Editor:

The Royal Artillery Institution has been approached who confirm that Gunners are popularly said to be either Poor, Proud or Prejudiced. This authority is undoubtedly unquestionable.

Memoirs

MAJOR-GENERAL F. S. G. PIGGOTT, CB, DSO, COLONEL COMMANDANT RE (RETD)

Francis Stewart Gilderoy (Roy) Piggott was born on 18 March 1883, the elder son of Sir Francis Taylor Piggott, one time Legal Adviser to the Japanese Government and subsequently Attorney-General of Mauritius and Chief Justice of Hong Kong, and Lady Piggott. He was educated at Cheltenham at the Royal Military Academy, Woolwich and commissioned into the Royal Engineers on 4 February 1901.

In the whole of his almost forty year's service, over thirty were spent on the Staff, or on Special Duties, and less than ten in his own Corps.

After his normal Young Officer courses at Chatham he was sent on a Submarine Mining Course at Plymouth in the summer of 1903 before being posted to the 42nd (Fortress) Company at Portsea.

His first break with the Corps, which was greatly to influence his future career, occurred early in 1904. This country had recently concluded an alliance with Japan and on the outbreak of the Russo-Japanese War a number of British officers were attached as observers to the Japanese Army. Piggott was amongst the first twelve chosen and, due to this unique experience, he qualified as a First Class Interpreter in Japanese and acquired a detailed knowledge of the organization and working of the Japanese Army.

On returning from the Far East in 1906 at the conclusion of the war he was posted to Gibraltar where he remained for two years serving in the 15th (Fortress) Company and acting as Adjutant to Colonel Cecil Hill. Whilst serving on the Rock he met, and in 1909 married, Jane (Juanita) elder twin daughter of W. James Smith, Esq, JP, of Gibraltar and Villa Vieja, Algeciras. They had two sons and a daughter. The younger of his two sons, Lieutenant J. A. S. Piggott, the Nigeria Regiment, died on active service in East Africa in 1941. His second son is now Major-General F. J. C. Piggott, CB, CBE, DSO, Colonel of the Queen's Royal Survey Regiment. His wife died in 1955.

On returning home from Gibraltar in 1909 he took the Advanced Course at Chatham to qualify for promotion to Captain, after which he was posted to the 5th Field Company at Aldershot. He was also attached for brief periods to the Balloon School, and to the Air Line, Cable and Wireless Telegraph Companies, then also stationed at Aldershot. This tour of regimental duty was, however, soon to be cut short. There was at that time a reciprocal exchange of information between the British and Japanese Armies and Piggott was selected to return to Japan in 1910 to carry out liaison duties with the Japanese Army Engineers. In addition during his three-year stay in Japan he acted as an assistant to the British Military Attaché and attended many training exercises and manoeuvres.

After returning to England he was posted to the 30th (Fortress) Company at Plymouth and in early 1914, after a short time in command of the 18th (Fortress) Company at Falmouth, he was selected to become the Staff Officer to the Chief Engineer at Devonport—his former CO Colonel C. Hill.

His war service was spent almost entirely on the staff, becoming first a GSO 3 in the Far Eastern Intelligence Branch of the War Office. He then became Brigade Major of the 94th Infantry Brigade. He remained for eighteen months with the Brigade which was involved in the Defence of the Suez Canal and the First Battle of the Somme in 1916. During the Third Battle of Ypres he was a GSO 2 on the Headquarters of the 20th (Light) Division. During the Passchendaele operations of 1917 he became a GSO2 in the Headquarters Fifth Army; he later became GSO 1 (Intelligence) of the same Army. At that time Lieut-General Sir George Macdonogh was Director of Military Intelligence at the War Office, Brigadier E. W. Cox was the BGS Intelligence at the British GHQ in France, Lieut-Colonels A. R. C. Sandes and Piggott were GSO 1 of Armies—surely a unique Sapper record. The Official History of the 1914/18 War describes how, as a result of the sum of all the intelligence gained by these RE officers, the date, place and almost exact hour of the start of the March 1918 German offensive against the Fifth and Third Armies were accurately foretold. After the withdrawal of the Fifth Army from the line, Piggott took over the Intelligence Branch of the Second Army and was on General Plumer's staff during the Battle of the Lys and throughout the Advance to Victory. After the Armistice he remained with Second Army Headquarters for a while in Cologne.

For his war services he was mentioned in despatches five times, awarded the DSO in 1917 and received a brevet lieut-colonelcy. He was also created an Officer of the French Legion of Honour and the Belgian Order of Leopold and was awarded both the French and Belgian Croix de Guerre.

Together with ten other RE officers he was nominated to attend the first post-war Staff College Course at Camberley. He graduated at the end of 1919 and then spent two years in the Military Directorate at the War Office covering the Russian and Far Eastern Sections. During this period the Crown Prince of Japan (later to become the Emperor) visited England and Piggott was attached to his suite. In 1921 he was selected to become Military Attaché at Tokyo, and on his way to Japan took part in the Washington Conference of that year on the limitations of armaments. During his five years as Military Attaché he enjoyed the friendship of the Crown Prince and renewed acquaintances made during his previous tour of duty in the country. The then Chief of Staff of the Japanese Army, Marshal Viscount Uehara, was also himself an Engineer officer and Piggott rapidly gained his confidence.

On returning from Japan he attended a Senior Officers' War Course at Greenwich and in July 1927 he became a GSO1 at the War Office under Lieut-General Sir Ronald Charles, later to become Chief Royal Engineer, and for the next three and a half years dealt with problems concerning the USA, Central and South America, Italy and the Balkans and the Far East. He was then selected to become Deputy Military Secretary—the third successive Royal Engineer officer to hold the post. His appointment was extended to cover the deliberations of the Stanhope Committee on promotion and lasted four and a half years.

He was promoted Major-General in June 1935 and the following spring he returned to Japan as Military Attaché for a second time. In addition to his normal work he carried out four special missions to China on behalf of the Foreign Office to compose difficulties and disagreements there between the British and the Japanese invading forces. On the last occasion he secured the release of Colonel Spears and received the personal thanks of the Secretary of

State for Foreign Affairs. He retired in December 1939 and was made a Companion of the Bath in the Coronation Honours.

He became a Colonel Commandant RE in June 1941 and retired on completion of tenure in March 1951.

During the Second World War he was employed in 1941 and 1942 on the censorship of Japanese correspondence and from 1942 to 1946 he was a Senior Lecturer at the School of Oriental Studies of the University of London.

He was a Member of Council of Cheltenham College from 1930 to 1935, and President of the Cheltonian Society 1944 to 1946. He was a life member of the British Legion, having founded the branch at Ewhurst, Surrey where he lived for many years. On 1 January last year he became an honorary life member of the Army and Navy Club.

Although never an outstanding cricketer, he was a good all-round player. He was a member of the MCC, I Zingari and the Free Foresters. As a Corps Cricketer he had the almost unique experience of playing in the Gunner match of 1902 as a second-lieutenant and as a lieut-colonel over twenty years later.

From 1958 to 1961 he was Chairman of the Japan Society of London which he helped to revive after the Second World War and of which his father had been a co-founder in 1892. He was attached to the suite of the present Crown Prince of Japan before and during the Queen's Coronation in 1953. He worked unceasingly in the cause of Anglo-Japanese friendship and happily lived to see it restored after the disruptions of war. He wrote the *Elements of Soshu* in 1913 and in 1950 he published an autobiography *The Broken Thread*, the title symbolizing his deep concern over the relationship between the two countries. In 1958 he edited Mamoru Shigemitzu's book *Japan and her Destiny*. His devotion to the cause of good Anglo-Japanese relations and his loyalty to his Japanese friends were fully appreciated in Japan and in 1955 after the death of his wife, also well-loved in Japan, he visited Tokyo as guest of the Foreign Minister. He was admitted to both the Order of the Rising Sun and the Order of the Sacred Treasure of Japan.

He died peacefully in a nursing home on 26 April last aged 83 years.

MAJOR-GENERAL THE REVEREND D. W. PRICE, CB, CBE

Denis Walter Price was born in Kandy, Ceylon on 28 October 1908, the son of Walter Cromwell Price, Esq. He was educated at Blundell's School and the Royal Military Academy, Woolwich where he was awarded the King's Gold Medal and represented the Shop at athletics. He was commissioned into the Royal Engineers on 31 January 1929.

As a subaltern Price was an outstanding athlete. Whilst up at Cambridge during his YO Course he was awarded an Athletics Blue. He set up a record for the One Mile at Fenners which was not beaten for many years; with a brother Sapper officer, E. W. Denison, he took part in 1931 in one of the most famous Inter-Varsity Three Mile races won by Denison by half a second from the Oxford first string, Denis Price having acted as a valiant pace-maker throughout the race. He later won the Army One Mile Championship and ran for the Army at this distance for five years and for England in 1933. Denison won the Army Three Mile three times, represented the Army in that event for three years and, like Denis Price, gained international honours in 1933. These two young RE officers, together with others trained at Fenners, had a most remarkable effect on Corps Athletics during the thirties. A Sapper unit was in the final of the Army Championship from 1930 to 1936. The Training Battalion was fourth in 1930, third in 1931 and won the Championship in 1935 and 1936, setting up five Army team records in both track and field events. RE Aldershot figured among the runners-up on several occasions, and a team of four distance runners, originally from the 38th Field Company, achieved consistent successes, providing the winner of the Army Individual Three Miles five times and of the One Mile twice, setting up records which stood unbroken for very many years. In all this Denis Price, who after finishing his YO Course at Chatham and Cambridge served as a company officer in 38th Field Company at Aldershot from 1932 to 1934 and as a posted officer in the Training Battalion RE at Chatham from 1934 to 1936, was a leading light both as a great performer himself and as an enthusiastic and dedicated trainer of others. Athletics, however, were not Denis Prices' sole vocation. He entered wholeheartedly into all unit activities, both social and sporting, and whilst at Aldershot he hunted regularly for two seasons with the Garth, South Berks and Vine Foxhounds, going across country with the best of them.

In 1936 he was employed under the Air Ministry on survey work in Iraq and on returning home two years later he was selected to become a company officer at the Royal Military Academy, Woolwich, and he was so employed when the Shop closed down, never to reopen, on 1 September 1939 on general mobilization.

His war time service was spent largely in Combined Operations, and promotion was rapid. Early in 1941 he became DAQMG of the Royal Marine Division, and at the end of the year he was promoted to become a GSOI at Combined Operations Headquarters. After a brief tour of duty in the USA in 1943 he became a Brigadier and assumed the appointment of Head of the Combined Operations Staff at the Headquarters, Supreme Allied Command South East Asia in March 1944. In the 1945 New Year's Honours List he was created CBE. In July of that year, to gain operational experience, he was posted to become Commander 41 (Indian) Beach Group.

After the cessation of hostilities against Japan he became CRE 5 Indian Division and FORCE 110 sent to restore order in the Dutch East Indies.

He returned home in 1947 to take up a GSOI appointment in the Military Intelligence Branch of the War Office. He later attended a post-war Staff Course at Camberley and on graduating from there he was appointed Colonel GS London Echelon of the Headquarters Western Europe Commander-in-Chief's Committee a post he held for two years before becoming a Colonel GS at SHAPE.

On 9 June 1951 he married Audrey, daughter of Mr and Mrs Henry De Beaufort. They had two sons and two daughters.

From SHAPE he was selected to attend the Imperial Defence College, and in January 1953, a Brigadier once more, he was appointed DAG at GHQ FARELF. In May 1956 he became Commander British Services Security Organization in BAOR and from 1959 until his retirement in November 1962 he was Chief of Staff, British Defence Staffs in Washington with the rank of Major-General. He was created CB in 1961.

During his last appointment he and his wife and family attended regularly the Trinity Presbyterian Church at Arlington, Virginia, and after his retirement from the service they returned to the United States where, having received a vocation to become a Minister of the Church, David Price entered the Union Theological Seminary Richmond, Virginia for the three-year course of a Bachelor of Divinity Degree. It was typical of him to be determined to make himself as professionally proficient in the Ministry as he had been in the Profession of Arms. In May 1963 his course of studies was interrupted by illness. However, by a special dispensation he was ordained at Trinity Church, Arlington on 8 December 1963. In September 1964 he was installed as Pastor of the High Bridge Presbyterian Church Natural Bridge, Virginia. Though his constant fight with cancer necessitated frequent visits to hospital at Bethesda, Maryland he maintained a full and effective ministry at his church at High Bridge earning the respect and love of his congregation and the whole community. He completed his Christmas pastoral duties and then once more entered the Bethesda Hospital where his influence was widespread. Having fought the good fight and kept the faith to the end, he died on 19 March—Saint Joseph's Day—1966.

His funeral at High Bridge Presbyterian Church on 23 March was attended by over two hundred persons who came to pay their last respects to their beloved pastor. Colonel D. Sherret, MC, represented the British Army. The surrounding beautiful Virginian countryside, bathed in spring sunshine, was a fitting setting for the laying to rest of a great Sapper officer and true Christian gentleman.

BRIGADIER J. A. C. PENNYCUICK, DSO*

JAMES ALEXANDER PENNYCUICK was born on 9 June 1890, the son of C. E. D. Pennycuick, Esq, CMG, of the Ceylon Civil Service. He was educated at Loretto and the Royal Military Academy, Woolwich, where he won the Armstrong Memorial Medal. He was commissioned into the Royal Engineers on 23 July 1910.

After completing his Young Officer training he was posted to 59 Field Company, then stationed at the Curragh. On the outbreak of the First World War on 4 August 1914 his Company was hurriedly mobilized and joined the British Expeditionary Force on the Western Front and took part in the Retreat from Mons. On 23 August his Company was called upon to demolish three bridges under enemy fire, Lieutenant Pennycuick and his section successfully blowing a large plate girder railway bridge at Les Harbières. Three days later the Company assisted 19 Brigade in strengthening its position on the right flank of the 5th Division. There was very little time available but five trenches were hastily dug and communications improved. The trenches were manned by the retreating infantry and by the Sappers who had dug them. When the trenches became overcrowded the Sappers left them for the infantry to man and took up firing positions in the open, where they came under heavy shrapnel fire. Their efforts, however, materially helped to stem the enemy's advance and enabled the Brigade to withdraw intact. On 30 August, Lieutenant C. A. West[1] brought a message from the CRE to Major Walker, who commanded 59 Field Company, saying that the suspension bridge at Pontoise was not completely demolished and passable. Lieutenant Pennycuick and Lieutenant West immediately volunteered to go back to complete the demolition. Carrying the explosive on a motor-cycle the two officers set off and managed to demolish the bridge just before the leading elements of the enemy arrived. For this exploit both officers were awarded the DSO. Early in 1915 his Company worked closely with 171 Tunnelling Company then engaged in driving mine galleries under Hill 60 which were blown on 17 April. In June of that year he was officially attached to 171 Tunnelling Company. In September 1915, after being wounded, Pennycuick was posted to the Engineer Training Centre at Newark but he returned to the Western Front in July 1916 where he was given command of 83 Field Company of the 20th Division which was later engaged in the Battle of the Somme and the action at Guillemont in September of that year. Wounded a second time, he was not out of the fight for long and in March 1917 he was given command of 154 Field Company of the 37th Division and took part in the Battle of Arras where he was awarded a bar to his DSO for conspicuous gallantry and devotion to duty during lengthy operations where he was largely responsible for consolidating positions gained, constructing strong points and trenches in most exposed positions and, notwithstanding heavy casualties, by his personal courage and skill enabled the work to be successfully performed and the positions rendered secure. He later became a GSO3 (Intelligence) at GHQ in France and from April to September 1919 he was Staff Officer to the Chief Engineer IV Corps of Rhine Army.

[1] Now Major-General C. A. West, CB, DSO, MC.

Besides his DSO and bar he was mentioned in despatches three times for his war service and awarded the Russian Order of St Anne "for valour in war".

Returning from the Rhine Army he was posted to Chatham as an Assistant Instructor in Fortifications, and during the two years in that appointment he was the Hon Treasurer and a Whip to the RE Beagles. He also found the time to study for the Staff College and he passed first on the list into Camberley in 1922.

His first staff appointment was as a Staff Captain in the AG3 Branch of the War Office. After two years there he was posted to India where he was employed successively as a DAAG in the Adjutant General's Branch, Army Headquarters and Brigade Major 10 Infantry Brigade at Jubbulpore.

In June 1931, on reverting to the home establishment, he became DCRE at Dover. In January the following year he received a brevet lieutenant-colonelcy and was posted to the Military Intelligence Branch of the War Office where he was employed on "special duties".

In January 1935 he was appointed CRE Catterick Area and 5th Division. In April 1938, on promotion to Colonel, he went as Chief Engineer to Malaya where many large projects were in hand. On the outbreak of war in 1939 the works responsibility further increased and the Chief Engineer's appointment was upgraded and he became a Brigadier. In August 1941 he was relieved by Brigadier I. Simson who, with many others, was later to become a prisoner of war in Japanese hands.

Although officially due to retire, he was retained to serve with the Allied Control Commission in Italy until the end of the war. He was largely responsible for the restoration of the Naples electricity power supply and other similar large engineering projects.

Brigadier Pennycuick was a frequent contributor to the *RE Journal*. Between the two world wars he wrote articles on the organization of the Army and on pontoon equipment and its carriage and other technical articles. After the Second World War he contributed articles on engineering projects undertaken by the Control Commission in Italy and a series of historical articles dealing with the Battles of Arras and Guillemont and, quite recently, he wrote an article on the tunnelling operations against Hill 60 and Messines Ridge.

He died on 21 February 1966 of heart failure, aged 75 years.

In April 1923 he married at Gressenhall, Norfolk, Marjorie, third daughter of Sir Ralph Hare, Bt, and Lady Florence Hare. They had one son and two daughters.

COLONEL C. P. GUNTER, CIE, OBE

COLONEL CLARENCE PRESTON GUNTER, *one-time* Director of the Survey of India, died on 12 November 1965, aged 92 years.

The son of Colonel Howel Gunter, the Black Watch, he was educated at Westward Ho! and King William's College, Isle of Man; he passed into the Royal Military Academy, Woolwich, and was commissioned as a 2nd Lieutenant RE in February 1893.

After his Chatham training he was posted to India where his first appointments were with the Military Works Department at Meerut and at Dehra Dun and later with the PWD at Rawalpindi. Due to a severe illness he was invalided home, but he returned to India in 1898 and took part in the Tirah Campaign as an Assistant Field Engineer. In December 1899 he was posted to the Survey of India, Dehra Dun and he stayed "in survey" for the remainder of his service.

His early survey duties took him to Assam and to Burma. From November 1911 to February 1912 he was one of the two survey officers who accompanied the Mishmi Mission whose aim was to improve communications through the North Eastern Province towards China, and the following year he carried out detailed surveys in that area. In March 1913 he was promoted major and made Deputy Superintendent Survey of India at Shillong, Assam.

During the 1914–18 War he served in Mesopotamia in charge of the Map Compilation Section at Tigris Corps Headquarters. According to the War Record of the Records of the Survey of India, "The organization and expansion of this Section was the constant concern of Major Gunter, and it was due to his untiring energy that the Expeditionary Force in Mesopotamia was never again destitute of accurate maps for its operations. The work of this Section, upon which all subsequent operations were based, laid the foundation for their success." In November 1916 an Air-Photo Section was added to his Map Compilation Section and his appointment upgraded to Lieut-Colonel. Early in 1919 he officiated as Deputy Director of Survey, Mesopotamia. For his war services he was twice mentioned in despatches, received a brevet lieutenant colonelcy in 1917 and was awarded the OBE in 1918.

Returning to India after the war he became Superintendent, Survey of India at Bangalore; he then took up similar appointments at Maymyo and Simla. In 1925 he attended the Inter-National Geographical Congress in Cairo as the Survey of India's representative. For the last six months of 1926 he officiated as Surveyor General of India and early the following year he was appointed Director, Survey of India which post he held until his retirement in May 1928, when he was created CIE.

In May 1919 he married Pansy, daughter of the Countess d' Epineuil. They had two daughters. His wife died in 1957.

COLONEL R. A. V. G. E. S. MONTEITH

ROBERT ARTHUR VERNON GEORGE EDWARD STUART MONTEITH was born on 13 December 1898, the elder son of Lieut-Colonel E. V. P. Monteith of Jacob's Horse. On passing out of the Royal Military Academy, Woolwich he was commissioned into the Royal Engineers on 25 January 1918.

After his Young Officer training at Chatham he was posted to the British Army of Occupation on the Rhine early in 1919 where he stayed for a year. He then attended a short course in defence electric lights at Gosport before being posted to India.

On arriving in India he served firstly with the Royal Bombay Sappers & Miners at Kirkee and then joined the Bengal Sappers & Miners at Roorkee where he became Assistant Adjutant and Mess Secretary.

In September 1923 he returned home to complete a Supplementary Course at Chatham and Cambridge University, at the conclusion of which he was posted as an Assistant Divisional Officer at Hipswell. On promotion to Captain in January 1929 he was given command of 39 (Fortress) Company at Sheerness and in July of that year he married Joscelyne, youngest daughter of Thomas W. Marley, Esq, JP and Mrs Marley of Cote House, Darlington.

After a two-year tour in command of 39 (Fortress) Company he was appointed Adjutant to the Hampshire Fortress Companies RE (TA) with his headquarters at Portsmouth.

Returning to India in 1935 he served in the Military Engineering Service as Garrison Engineer Ishapure and as ACRE Fort William, Calcutta. On promotion to Major in January 1938 he was posted to Shillong as Garrison Engineer. He was home on leave when war broke out the following year and he did not go back to India.

His service during the Second World War was spent mostly with the Central Mediterranean Force and in December 1944 he became a Commander Army Group RE In Italy. From September to December 1945, as an Acting Brigadier, he held a Chief Engineer's appointment. On the cessation of hostilities he became a CRE in CMF and early the following year he returned home to become Officer in Charge of RE Records—a post he held until his retirement in July 1949. The Other Rank strength of the Corps at the end of the war amounted to almost a quarter of a million, and Colonel Monteith's task as Officer i/c RE Records during the first post-war years which saw the rapid reduction in the size of the Corps, based on age and service group run out, was a most taxing one.

After retirement he put aside an intention to become a schoolmaster and remained with the Corps as a retired officer in the Headquarters Army Emergency Reserve (Field and Works) at Ripon.

He died on 30 November 1965 in Ripon Hospital in his sixty-seventh year.

COLONEL SIR CUSACK WALTON, DSO

Cusack Walton, one time General Manager of the Indian North Western (now Pakistan Western) Railway, died on 27 February 1966 aged 88 years.

He was born on 26 February 1878, the eldest son of F. T. Granville Watson Esq, CIE, MICE, a distinguished Indian Railway engineer. His younger brother, also a Sapper officer, Colonel G. Walton, CMG, OBE, DL, JP, augmented the family connexion with the Indian State Railways and served with distinction on the North Western Railway contemporaneously with his elder brother before the First World War.

Posted to India after his Chatham training he served for just over a year in a Military Works Service appointment at Bareilly. Then began his long and outstanding career with the North Western Railway in which he served almost continuously, except for the First World War years when he returned to military duty, rising from Assistant Engineer 3rd Grade to Agent and General Manager.

Taking up his first 3rd Grade appointment at Bareilly he later held similar posts at Lahore and Sakaranpur.

In November 1902 he went as an assistant to Lieut-Colonel L. E. Hopkins, DSO, OBE, RE, on a reconnaissance for a strategic railway to run from Spezand, south of Quetta, through Nuski to Duzdap, skirting the southern boundary of Afghanistan, and finishing close to the Persian border. They surveyed a proposed alignment through the Nuski Ghat which involved a descent of 2,000 ft from Quetta to Nuski. In November the following year work started on the Niphpa tunnel, driven half a mile through solid rock, and some 20 miles of the line each side of it, and Walton was placed in charge of the construction of 30 miles of line to the south. Work was carried out at an altitude of 6,000 ft above sea level and often hindered by terrific winter blizzards.

In 1906 he was promoted Assistant Engineer 2nd Grade at Peshawar. During a long leave home he married Julia Margaret, the only child of the Reverend D. M. Gardner, DCL, formerly of the Indian Civil Service and afterwards Rector of Great Rollright, Oxfordshire, and Mrs Gardner on 24 November 1909 at St Luke's Church, Greyshott. He returned to India in 1910 where he was employed as executive officer in charge of the building of the Lower Ganges railway bridge at Sara under Sir Rupert Gales. The project was of special interest to him, his father having previously supervised the construction of the railway bridge over the Ganges at Benares, some 400 miles to the west.

Recalled for military service on the outbreak of the First World War, he was employed in the Transportation Directorate in France and Belgium. Later he became Assistant Director of Railway Construction on the Italian Front, and he finished the war as Assistant Director-General of Transportation of the British Armies in France. He received a brevet colonelcy in January 1918. He was awarded the DSO in 1916, and was invested as an officer of the French Legion of Honour and the Order of the Crown of Belgium.

Towards the end of 1919 he returned to India and the following year he was appointed Senior Departmental Agent of the North Western Railway. In 1925 he became Agent and General Manager which appointment he held until his retirement in February 1933 when he was knighted for his outstanding services to the Indian State Railways.

Writing about Walton's administration as Agent and General Manager of the North Western Railway, Lieut-Colonel E. W. C. Sandes in his book *The Military Engineer in India* says that it was notable for the tact, firmness and sympathy which he displayed in handling 200 officers and some 120,000 men during a heavy programme of new construction and reorganization carried out during a difficult time of political unrest. The railway arrangements for the defence of the NW Frontier required particular attention, and the nucleus of a depot of a Railway Reserve Regiment, many thousands strong, was opened in Lahore. In a speech, delivered at Lahore in 1922, Colonel Walton said: "Men are of more importance than machines. We have specialists to look after our machines. How much more are they needed for the care of men". True to his ideals, he established a special Personnel Branch to look after the men; he formed Labour Bureaux with Area Councils and Staff Committees to look into grievances; he founded a Training School; he improved the men's quarters and gave them every means of recreation and sport. In brief he undoubtedly treated those under him as individuals rather than as machines and the result was an efficient and contented army of workers when he retired in February 1933 to receive his well-earned knighthood. His wife was awarded the Kaisar-i-Hind Medal for her services to India and its people, also a fitting tribute to the work they had shared.

Throughout his long service in India he had always taken a great personal interest in the work of the Christian Missions and, like his brother who after retirement devoted himself to the Boy Scout Movement, he immersed himself in honorary work when his service days were over. From 1934 to 1938 he was Honorary Secretary of the India, Ceylon and Persia Missions and the Church Missionary Society. He later became a Vice-President of the British and Foreign Bible Society and the Church Missionary Society.

LIEUT-COLONEL R. A. CONLAY

Ralph Archibold Conlay, who died at Bexhill-on-Sea on 30 March 1966, was the son of the late W. L. Conlay Esq, Commissioner of Police, Malaya. Educated at Cheltenham College, he entered the Shop in 1921, and was commissioned in the Corps on 31 January 1923.

He embarked for India in 1925, and remained on the Indian Establishment of the Corps for twenty-two years, until reverting Home in 1947.

Ralph had a bent towards mechanics and mathematics. He took an E and M course, and was one of those unassuming, conscientious, and very energetic Sappers who have always done so much of the real work of the Corps. Except for a brief tour as Staff Officer for Personnel with the Engineer-in-Chief at Simla Headquarters, he was always to be found where the burden was heaviest, and the heat of the day, hottest.

War service took him to the building of airfields and petrol installations in Northern Assam. At the end of the war he worked in the Directorate of Munitions Production, India, where the major planning of India's war effort was taking place. From there he moved on to the execution of the field investigations for the Damodar River Project, Bihar.

On reversion to the Home Establishment in 1947, Ralph Conlay became CRE London District at a busy time, when the end-of-war disorder was still being cleared up, and the major reconstruction of barracks and military establishments was being planned and put into execution. He held this appointment until his retirement in 1952, when he became, as a "Retired Officer", Garrison Engineer, Woolwich, a posting inside his own recent CRE's charge. This is unusual but, of course, it did not trouble Ralph, who was quite unconcerned with questions of rank and prestige so long as he had an honest job of work to do.

In his later years he moved from his home in Mayfield to Bexhill-on-Sea, where his energy still remained high, despite failing health.

Tributes received after his death reveal his many voluntary activities. Of some of these, even his close friends, who thought they knew him well, were unaware. He worked on social service with the Sisters of St Anne, and was Treasurer of the Beth Holme House Children's Holiday Fund, and of the local branch of the Conservative Association. Even these activities did not satisfy his zeal and abounding energy. He was a keen gardener, and undertook, from time to time, the tutoring of children in mathematics, a subject in which he had never lost his interest.

Ralph was a true Sapper, able to turn his hand to anything. He will be sadly missed. It is only to be hoped that the Corps retains its ability to raise officers like this.

He married Sylvia MacNaughton in 1932 at The Holy Trinity Church, Brompton, London, and leaves his widow, three daughters and two grandsons to mourn his loss. Our sympathy goes out to them.

C.F.W.M.

Book Reviews

HISTORY OF THE SECOND WORLD WAR, SOE IN FRANCE

By M. R. D. Foot

(Published by Her Majesty's Stationery Office. Price 45*s*)

On 15 April this year the first of a series of Anglo-French ceremonies commemorating the 900th anniversary of the Norman conquest of England was held at Beg Hellouin in Normandy. A tablet was unveiled in the courtyard of the Abbey, from which Lanfranc set out to be Archbishop of Canterbury and later the monk Gundolfus set out to be King William's Chief Engineer. The tablet was a memorial to "All Normans of France and England who over the centuries died fighting each other or fighting side by side". The ceremony was attended by the British Ambassador and M. Alexandre Sanguinetti, the French Minister for ex-Servicemen. M. Sanguinetti in his speech said that during the days and nights of their worst defeat the popular French hope clung to the Cliffs of Dover and the peals of Big Ben. He might have added the BBC broadcasts also. French people of this and preceding generations, he said, would not forget their debt of gratitude.

This Volume of the History of the Second World War, recounting the work of the British Special Operations in France from 1940 to 1944, tells the story of a gallant band of eighteen hundred men and women sent clandestinely by plane, parachute and submarine from across the Channel and from North Africa to direct and organize rebellion against the established regime of Pétain and to harass the Nazi tyranny in occupied France.

In spite of his great age General Pétain was an imposing figurehead, and he was supported by most of the great banking and business houses, the Hierarchy of the Church, eminent intellectuals and leading members of the bar and the French Civil Service. The French National Committee, set up in London, was self-appointed and, although de Gaulle was recognized by the British Government as the "leader" of all Free Frenchmen wherever they might be, he was denied formal recognition as the head of any sort of de facto or de jure government; whilst in France he was, at first, shrugged off as an impractical visionary. The German forces had shown themselves invincible in battle and they were absolutely ruthless as the instrument of an occupying power.

The early days of the SOE were, therefore, fraught with difficulties. By sheer chance the initial heads of two Sections of SOE (D and MIR) were regular Sapper officers and the senior members of the staff were mostly drawn from the "Public School" class. This social uniformity among the staff was not to be found amongst the agents, both men and women. Their diversity was marked and to quote the author of the book, it ranged from "pimps and princesses". The British element was highly skilled in sabotage raids against selected targets, but the stirring up of rebellion was foreign to their nature. Amongst the others, each had his or her own idea of what type of liberated French government they wished to see eventually set up; those with communist leanings had the clearest idea and were the best professional wreckers of an established regime, the best organized and hence often the most successful agents. At the time their use was willingly countenanced; Uncle Joe Stalin was our Ally. To further complicate matters most of the French agents laboured under a quite unfounded delusion that their British colleagues were only intent upon a Norman Conquest in reverse.

Due to linguistic difficulties training was difficult and, as SOE was often regarded as a "side show", it was not always possible to get the equipments, communications and transportation needed to carry out missions. Although all the agents employed were dedicated and extremely brave, some at times displayed almost crass stupidity;

a few were unable to withstand their captors' merciless interrogation and there was often a mutual distrust between various "circuits". Some indeed died fighting or betraying each other, but most who gave their lives did so in a common cause.

A true assessment of the value of the SOE to ultimate victory will perhaps never be known. The history, however, quotes a post-hostilities SHAEF evaluation that "without the organization, communications, material, training and leadership which the SOE supplied, the Resistance would have been of no military value". This is the official recognition that the work and sacrifice of so many brave men and women had not been in vain.

The publication of this official history has given rise to questions in Parliament, letters to *The Times*, a leader in that newspaper and other outbursts in the press, and a programme on the BBC.

The Government had originally intended that the SOE archives should be kept secret. However, as accounts of the activities of several individual agents employed by the organization had been given often flamboyant notoriety in several books, in serials in the newspapers and in screen and television plays, it was decided that an official, "accurate and dispassionate" history should be written and Mr M. R. D. Foot, the distinguished Oxford historian, was engaged as author. Many restrictions, nevertheless, were put in his way; he was not given access to all the available documents and much importance was given to keeping him "out of the way of interested parties". Throughout the writing of this official history the restriction on the availability of documents was studiously maintained, however, some of those about whom he was writing knew what was happening and were able to comment on his manuscript. Others were not so informed, nor given the chance to make any comment whatsoever. Amongst this latter category were some who had achieved a legendary fame and had been decorated for bravery. It was this harnessing by a faceless authority of an author of a volume of the Official History of the Second World War that aroused the controversy. Nevertheless Mr Foot has written with great skill and understanding and produced what must be one of the most fascinating and exciting stories of the war and one of the most damning indictments of German oppressive brutality and unbelievable savagery. It was not without avail that in their darkest days the people of France looked across the Channel for help against their inhuman oppressors.

IN THE WAKE OF THE GREAT

By Lieut-General Sir Gordon Macready

(Printed by William Clowes & Sons Ltd. Price £2 5*s*)

The author was in the Wake of the Great only in the sense that they were his leaders, in every other way he was right in among them and in the end became one of them.

His story spans sixty years, beginning in Ceylon where he was born in 1891, and ending with his retirement in Germany in 1951.

He touches on his early days at Cheltenham College and his adventures as a young RE officer, in which capacity he accompanied his field company to France in August 1914. Four months later he was transferred to a staff appointment and remained on the staff for the rest of the war.

In May 1918, he joined the Supreme War Council at Versailles, where he mingled with Allied leaders and politicians on whom he formed opinions which are both illuminating and shrewd. The six months he later spent in the Military Mission in Berlin and his year in Poland organizing the National Police Force gave him experiences of another kind, and the latter appointment was, to say the least of it, an unusual one for a Sapper officer still in his twenties.

From 1926 to 1933 he served in the Committee of Imperial Defence under the political direction of a Conservative Government, a Labour Government and a

Coalition Government, the personalities of all of them providing anecdotes which he retails with his usual light touch.

After a spell in the War Office, he became head of the British Military Mission to Egypt, where he witnessed the opening stages of the Second World War. In September 1940, he returned to the War Office as ACIGS and, as such, was closely concerned with the higher direction of the war. The account of his visit to Moscow with Lord Beaverbrook is exceptionally intriguing. In 1942, he took command of the British Army Staff in Washington and his description of the workings of the Combined Chiefs of Staffs Committee is admirably detailed and contains some lively personal vignettes of his leaders and colleagues. His tributes in this chapter to a fellow Cheltonian, Sir John Dill, are outstanding in their warmth and echo the feelings of our American allies for that great man. His treatment of the various high level conferences he attended in Washington, London, Quebec, Cairo, Teheran, Potsdam and Dumbarton Oaks bear out his claim that his book is not so much a history as a background to it—none the less interesting for that!

The last chapter deals with the five years, 1946–51, he spent as Regional Commissioner of Lower Saxony. Here one is struck with the breadth and clarity of his vision, and his ability to see clearly both the wood and the trees. The reconstruction virtually from scratch of a modern civilized country demanded all the high qualities he and his colleagues could bring to it. His record of their achievements is an epic that should be more widely known.

The epilogues by his wife and son round off the narrative with a picture of the man himself and the book would not have been complete without them. It is indeed a pity that a work of such great value and interest should have been privately published and should consequently not have had the circulation it undoubtedly deserves. A.D.C.

STRANGE BATTLE-GROUND

OFFICIAL HISTORY OF THE CANADIAN ARMY IN KOREA BY LIEUT-COLONEL H. F. WOOD

(Published by authority of the Canadian Minister of National Defence, printed by the Queen's Printer and Controller of Stationery, Ottawa. Price $8.50)

Although full access to all relevant official documents in the possession of the Department of Defence were made available to the author of this Official History, Lieut-Colonel Herbert Fairlie Wood of the Canadian Army Historical Section, the inferences drawn and the opinions expressed are those of the author himself and do not necessarily represent official views.

The author has confined himself as far as possible to the part played by the Canadians in Korea and references to the forces of the fifteen other nations employed there under the United Nations auspices only in so far as they affected the Canadian contingent. Contemporaneously with the Korean War a sudden threat of hostilities in NW Europe and the formation of NATO, the struggles within the United Nations and the problems of national defence arising from the development of inter-continental missiles shared the stage and complicated Canada's problems of allocation of funds and manpower resources, and these factors have been touched upon in the History.

The Korean War made relatively little impact on the Canadian public. The contribution to the "police action" in Korea and the casualty rate were relatively small. At no time during the conflict was it necessary to impose conscription and the average Canadian could go about his business in the welcome prosperity created by the new expenditures and enjoy reading spirited accounts of the actions fought by famous Canadian Regiments in a distant land. It was in the tradition of the nineteenth century and its frontier fighting and new to a Canada of the twentieth century in which the country had twice raised a large citizen-soldier army for defence against aggression. There was no Somme or Passchendaele, no Hong Kong, Dieppe, Hitler Line or Hochwald, and no Victory. However, there was no defeat and the Korean episode established for the first time in Canadian history a professional Army of international standing and the impressive number of honours and awards to officers and soldiers during the Korean campaign highlights the valour of that redoubtable force.

The author commanded a Canadian infantry battalion in Korea and writes with first hand personal knowledge.

The History contains excellent maps, sketches and diagrams and is well illustrated by a series of excellent photographs. The maps were drawn by Sergeant E. H. Ellevand of the Royal Canadian Engineers.

WEAPONS AND TACTICS—HASTINGS TO BERLIN

By JAC WELLER

(Published by Nicholas Vane. Price 35*s*)

The author should be no stranger to readers of this *Journal*. His book *Wellington in the Peninsula 1808–1804* was reviewed in our *Journal*, and his excellent article "*Wellington's Engineers*" was published in the September 1963 issue. Mr Weller is honorary curator of West Point Museum and a military historian of international repute. He is also an acknowledged expert on all forms of firearms and other military weapons.

In the preface to the book the author states that he has tried to write a book that will be a single source of information about military weapons and their tactical use from as far back as records go to the present day and how new weapons may be used tomorrow at "squad, platoon and company level". The result has been a most fascinating and instructive exposition, copiously illustrated and with excellent maps. The book describes first the weapons used and the tactics employed by the early Egyptians, the Persians, Greeks, Romans, Carthegenians, Goths, Vandals, Lombards, Franks, Huns and Mohammedans; it describes in exciting detail the Battle of Hastings and the emergence of the heavily armed knight. Reference is made to "Britain's Glorious Fourteenth Century" when the longbow won the day at Crécy, Poitiers and Agincourt. A chapter is devoted to the cannon, pike and musket. Other chapters describe the infantry weapons and tactics employed by Marlborough, Frederick, Napoleon and Wellington. In writing about the American Civil War the author explains how the defence was stronger than the attack. Even a defeated enemy could use its new "Minie" rifles to prevent an effective pursuit. The men on both sides were natural Sappers, skilled in the use of pick, shovel and axe, and the construction of field fortifications came naturally to them. The war was eventually won by the attrition and breakdown of the Confederate war potential and by the vast build-up in the north of manufacturing capability and dollars to finance recruit purchasing. Battles could still be won by men with their weapons, but the war winning importance of the home front effort in many different fields was to increase in geometric proportion. In the final chapters of the first section of the book, the author describes the phenominal growth in the fire power and destructiveness of weapons from the end of the Franco Prussian War of 1870 to the atomic bombs of August 1945.

The final chapters of the book deal with the historically fairly recent weapon systems and weapons policy of the United States Army and Marines, and those of East and West Germany, Red China, Canada, France, Italy, Greece and Turkey, the Benelux Countries and our own. In this last connexion it is a sobering thought to read the author's opinion, after a very full description of how we developed the tank and many other modern weapons, that "if total war should come, Britain would fulfil her NATO commitments but will not have mass armies of the WWI and WWII type. Forces of that size could not be supported by any industry and economy that might survive even limited nuclear attack".

COMPONENTS FOR PNEUMATIC CONTROLS INSTRUMENTS

By L. A. Zalmanzon

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 110*s*)

This book would be of great use to the designer of pneumatic systems associated with automatic control in large power installations, the aircraft industry and other specialized branches of engineering. It would also be of use to those responsible for operating and maintaining large advanced pneumatic control systems as, for those sufficiently educated to absorb the vast amount of theoretical information in the book, a knowledge of the static and dynamic characteristics of penumatic resistances, capacitances and transmission lines would give them a better understanding of their plant. It must be appreciated that this book contains theory only and that there is not one illustration of a pneumatic system, or pneumatic component, as it is in an installation. The first chapter, for example, devotes 72 pages to the theory of restrictions and the second devotes even more space to the static characteristics of pneumatic chambers.

It is not the book for the engineer interested in compressed air for construction work. Other much more elementary and practical books would suffice for this. But for the engineer who wants a complete knowledge of how gases behave in various circumstances, with the associated mathematics, one could hardly wish for a more complete work.

The book is generally well produced and the formulae and mathematics are clearly expressed, but certain of the graphs are reproduced to a very small scale indeed, with the various curves so close together that they are almost touching; one graph no larger than a postage stamp has no fewer than seven curves on it. In a book costing 110*s* one would have thought that there was no reason to be so mean with space, but this criticism only applies to a small proportion of the book. T.H.

ELEMENTARY MATHEMATICS FOR SCIENTISTS AND ENGINEERS

By M. D. Hatton, MSc, FIMA

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 21*s*)

This book is well named. It is aimed at first year students of engineering and science reading for degrees and diplomas in technology. The writer is Deputy Head of the Department of Mathematics, Battersea College of Technology. The book starts with differentiation and takes the reader through such subjects as curve sketching and conics, polar co-ordinates, approximations, etc, and ends up with differential equations and their applications.

There are many worked examples and exercises with answers, many of the questions being taken from University of London examination papers. The text is very clearly expressed and well printed. There is also a good index. At 21*s* the book is strongly recommended to those for whom it is written. Instructors also could make good use of it. T.H.

IMPELLER PUMPS

By Stephen Lazarkiewicz, MIPMechE

and

Adam T. Troskolanski, MIWSA

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 120*s*)

This book is a revised and enlarged version of the first 1965 Polish edition. The authors, S. Lazarkiewicz and A. T. Troskolanski, are respectively the Consulting Engineer of the Warsaw Pump Manufacturing Company; and Professor of Hydraulics at the Technical University, Wroclaw, Poland. Translation from the Polish was made by David K. Rutter, BSc(Eng).

The text is an up-to-date assessment of current international pumping practice and design knowledge compiled after consultation with thirty-nine manufacturers of pumps, of whom eighteen are British. It presents a record of what has already been achieved by impeller pumps of centrifugal, helical flow, diagnonal flow, propeller and axial type; but excludes the installations required to meet the super-critical pressures, large discharges, high speeds, and difficult conditions encountered in nuclear projects and other specialist forms of ultra modern industry. The latter will necessitate a departure from the usual form of impeller pump whose principles of design stem from before 1772. Readers may be surprised to learn from the book's historical section that a centrifugal pump using a double curvature wooden vane was discovered in a copper mine in San Domingos (Portugal) in that year.

The text is roughly divided into two parts, theory of design and practical application. The former, which includes the fundamental notions in the theory of impeller pumps, the basic quantities in the energy balance of pumps, flow through impellers, and the design of component parts, is excellently defined with a minimum of words and a wealth of curves, diagrams, and reasonably simple mathematical derivations and worked examples. The practical application section is largely descriptive and well illustrated. In a concise manner it highlights the construction, installation, testing and operation of all the usual forms of impeller pumps and includes an excellent summary of their performance characteristics, which is aided by fourteen separate drawings to larger scale that are pocketed in the back cover.

An additional chapter deals with the design, construction and use of scale models for preliminary investigation purposes.

This 650 page book is excellently printed and offers a range of information that would be useful in part to the layman executive, HNC student and graduate pump designers.

F.T.S.

PRODUCTS OF NUMBERS

By C. Attwood

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 17*s* 6*d*)

This book is No 7 of the Practical Tables Series in The Commonwealth and International Library of Science, Technology, Engineering and Liberal Studies published by Pergamon Press. All the tables in the series have been compiled by Mr C. Attwood the Principal, Apprentice Training, Ford Motor Company, Ltd, to meet the needs of instructors and students in Technical Secondary Schools, engineers, architects and draughtsmen.

These particular tables give the *Products of Numbers from 1 to 999 by Numbers from 1 to 100.* Notes for using the tables are included.

The products were computed by direct multiplication on a digital computer and checked to H. Zimmerman's *Calculating Tables* of 1904 which are of similar format. No discrepancies were found. All told the tables were checked four times, so their accuracy is reasonably assured.

Three historical plates are included and these help to alleviate the tedium of the printed figures. These are:—

The first page of four-page product tables in sexagesimals from *Protomathesis*, 1532, by Orontius Fineus.

A page from volume 4 of *La géometric pratique* . . . 1702, by Allain Manesson Mallet.

The title-page to first volume of first edition of *Rechentafeln* 1820, by August Leopold Crelle.

Users of the tables will no doubt be surprised to learn, like the reviewer, that A. M. Mallet "was a sergeant-major, engineer and teacher of mathematics at a military school".

F.T.S.

FRICTION AND WEAR IN MACHINERY
VOLUME 12, 1958

TRANSLATIONS FROM THE RUSSIAN EDITED BY G. HERRMANN

(Published by the American Society of Mechanical Engineers and distributed outside of the USA by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 70*s*)

This paper-backed volume is one of a series, of which Volumes 11, 14, 15 and 16 have already been reviewed in *RE Journals* of 1963 and 1965. Translation and publication in English was undertaken by the ASME with the aid of a grant from the US National Science Foundation.

The book contains translations of the 1958 collection of papers on the subject matter written by leading Russian scientists and engineers and issued by the USSR Academy of Sciences, through its Institute for the Science of Machines.

All the papers are of a specialized nature and only suitable for study by machine designers and engineers or chemists engaged on experimental lubrication work. Each paper is laid out in a set style, ie: the subject is introduced; preliminary considerations outlined; experiments described; results discussed and conclusions defined—all in considerable detail with diagrams, results curves, comparative tables and photographs. Also included is an extensive bibliography of other reading associated with the various subjects. Its use as a reference book to Russian practice is thereby enhanced.

The papers of this volume cover a wide range, from hydrodynamic lubrication and bearing performance to boundary lubrication, dry friction and wear. F.T.S.

AERIAL ROPEWAYS AND FUNICULAR RAILWAYS

By Z. SCHNEIGERT

Translation from the Polish edited by ZYGMUNT FRANKIEL, Engineering Publications Manager of British Ropeway Engineering Co, Ltd

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price £5 5s)

Any planner, economist, designer or engineer wishing to study an up-to-date summary of the subject matter could do no better than read this book. In 550 pages the author presents, in considerable detail over an international field, the history, development, design, construction, operation, testing, maintenance and costing of the various types of aerial ropeways and funicular railways used for passenger and industrial purposes.

The text is amplified with a large number of photographs, engineer drawings and diagrams which illustrate routes, profiles of travel, and a variety of components ranging from cable clamps to passenger cabins and stations.

Field engineers will find the detailed text and calculations of those sections dealing with steel ropes, trestles and supports, of unique practical value. F.T.S.

SECOND LAW OF THERMODYNAMICS

By S. R. MONTGOMERY, MA, SM, ScD, AMIMECHE, Senior Lecturer in Mechanical Engineering, University College, London

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 17*s* 6*d*)

This short, low-priced, soft-covered book, which is included in the *Thermodynamics and Fluid Mechanics Division* of Pergamon's Commonwealth and International Library, expounds and develops by means of corollaries the theory of the Second Law which, in other more elementary textbooks, is usually defined in a manner similar to that which follows:—"there is no process by which heat may be conveyed from one body to another at a higher temperature without the expenditure of mechanical energy".

Chapters are also devoted to:—the study of entrophy; the availability of energy and irreversibility in simple systems in equilibrium states; and applications to more complex systems. F.T.S.

MODEL ANALYSIS OF PLANE STRUCTURES

By T. M. Charlton, BSc (Eng), MA, MICE, Professor of Civil Engineering, The Queen's University of Belfast

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 12*s* 6*d*)

This book replaces the author's previous work *Model Analysis of Structures* published by Spon (London 1954). It is included in the *Structures and Solid Body Mechanics Division* of the Commonwealth and International Library published by Pergamon Press Ltd.

The text outlines the theory and practice of an alternative process of structural analysis to those employing numerical calculation or automatic computation which, if applied with care, can produce results that are generally within 5 to 10 per cent of the correct values obtained by the use of mathematics.

It discusses the principles and methods of use for indirect and direct analysis by scale model tests which can now be utilized in modern design offices to obtain influence lines of forces and bending moments, or strains or deformations due to specific loading, including lines of deformation. Design model analysis also presents a means for determining the strength and economy of complex structural forms such as shells, domes, concrete bridges, and the effects of wind on tall buildings.

The flexural similarity of structures is also explained, and a chapter outlines the methods employed to manufacture model frameworks and recommends the materials suitable for use. Three appendices cover:—

A bibliography of associated reading.

The principle of virtual work applied to frameworks.

One way of verification of analysis of portal frameworks.

This book would be of value to final year students of civil and structural engineering in universities and technical colleges, and to practising engineers concerned with the design and analysis of structures. F.T.S.

THE MECHANICAL BEHAVIOUR OF ENGINEERING MATERIALS

By W. D. Biggs, A Met, BSc, MA, PhD, Engineering Dept, University of Cambridge

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price £1 1*s*)

This soft-covered book is included in the *Structures and Solid Body Mechanics Division* of the Commonwealth and International Library published by Pergamon Press Ltd.

In recent years the environmental conditions and other factors which engineering structures are expected to withstand are such that the evaluation of the properties and behaviour of materials requires study at microscopic and submicroscopic level when the materials are considered at atomic or molecular size. It is, therefore, the object of the author firstly to relate the properties of materials and their structure, and secondly provide a theoretical basis on which to extrapolate when conditions or materials are outside those of known experience. Emphasis has been placed on metals and alloys, the other non-crystalline solids are treated less fully.

The text is largely descriptive and illustrated with diagrams and characteristic curves; the chapter headings are:—Constitution: Heterogeneity: Elastic Solids: Departures from Ideal Elasticity: Plasticity: Fracture: Tensile and Hardness Tests: Creep, Fatigue and Impact Tests: the Selection of Materials of Construction.

In the chapters dealing with tests the author assumes that the reader has a broad knowledge of equipment and procedures used, and restricts his discussion to those features of the various conventional tests which are measured as mechanical properties.

The text is written at a level which is suitable for students in the first year of a degree course in engineering. F.T.S.

AN INTRODUCTION TO INDUSTRIAL FINISHING EQUIPMENT

By BRIAN F. BLUNDELL

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 37*s* 6*d*)

The author, chief draughtsman of Roto-Finish Ltd, Kalamazoo, Michigan, USA, compiled the text to provide an introduction to the chief production methods of finishing, and to make apparent the limitations imposed on machine design by the processes used, and vice-versa. In so doing he has provided a basic knowledge for the design of finishing equipment.

The information given is based on the experience gathered by the author whilst in the employment of Roto-Finish Ltd, and is intended to be suitable for draughtsmen and engineers who may be required to specify, select and instal industrial finishing equipment.

The result is a concise, easy-to-understand summary that covers most types of present-day mechanical and chemical finishing and drying equipment. The various processes used are explained with a large number of explanatory sketches and diagrams, comparative tables and photographs of English, American and German apparatus.

For good measure the author has included chapters on the electrolytic and ultrasonic processes and, throughout, a variety of snippets of information dealing with machining operations, health and operator welfare considerations. Attention is also drawn to the necessity of complying with certain factory acts when equipment is being installed.

In a world of intense industrial competition, high pressure salesmanship and advertising literature, in which the finished appearance of a marketable item plays an important part, this book should find a host of interested readers.

F.T.S.

MECHANICS OF MACHINES—VOLUME 2

By H. E. BARNACLE, BSc (LOND), AMIMECHE
(Senior Lecturer in Mechanical Engineering)
and G. E. WALKER, MIMECHE
Head of School of Civil and Mechanical Engineering, College of Technology, Oxford
(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 20*s*)

This soft-covered book is the second of two volumes on the subject matter which are included in the Mechanical Engineering Division of the Commonwealth and International Library published by Pergamon Press Ltd. Volume I was reviewed in the *RE Journal* for June 1965.

Both volumes investigate and analyse the nature and extent of the forces and motions to which machines and their parts are subjected. This volume deals specifically with: Acceleration in Link Mechanisms; Belt Drives and Shoe Brakes; Toothed Gears and Gear Trains; Engine Balance; Gyroscopic Action; Vibrations; General Dynamics and Automatic Control. An emphasis has been given to dynamics.

The text covers the requirements of students taking HNC, HND, the Diploma in Technology, or the external degree of BSc of London University. Each subject chapter gives calculation examples and worked solutions.

With the permission of the Senate of the University of London and the Institution of Mechanical Engineers, the author has included a number of appropriate examination questions—with answers.

F.T.S.

A COURSE OF MATHEMATICS FOR ENGINEERS AND SCIENTISTS VOLUME 6—ADVANCED THEORETICAL MECHANICS

By C. Plumpton and B. H. Chirgwin, Dept of Mathematics, Queen Mary College, University of London

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 50*s*)

This is the sixth volume of a seven volume work which covers the mathematics required by science and engineering students during their undergraduate studies. The earlier volumes lead on from senior school mathematics while the later volumes are concerned with the more advanced topics and methods used in chemistry, physics and engineering.

Thus this volume, which deals with mechanics of three dimensions, assumes the reader is able to make use of the concepts and methods such as matrices, vectors, tensors and transformation methods covered by volumes IV and V.

There are eleven chapters titled: Kinematics in Three Dimensions; Sets of Forces—Equilibrium; The Dynamics of a Particle; The Motion of a System of Particles; Gyroscopic Motion—Free Rotation and Steady Motion; Lagrange's Equations; Stability of Motion; Impulsive Motion; The Oscillations of a Dynamic System with a Finite Number of Degrees of Freedom—Normal Modes; The Vibration of Strings; Analytical Dynamics.

Each chapter includes a number of worked examples and a set of practice questions (with answers) for readers. The questions used were previously included in the examinations of Oxford University, the Syndics of the Cambridge University Press and the Senate of the University of London.

This volume will be useful for students taking honours courses in mathematics, and for those studying physics and engineering who meet problems of theoretical mechanics in three dimensions and analytical mechanics in their work.

F.T.S.

MATERIALS TECHNOLOGY IN STEAM REFORMING PROCESSES

Edited by C. Edeleanu

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 90*s*)

This book records the Proceedings of the Materials Technology Symposium held on 21/22 October 1964, by the Agricultural Division of Imperial Chemical Industries Ltd. It is included in the Symposium Publications Division of Pergamon Press.

The text deals with the application of high temperature technology in relation to the materials used in chemical engineering plant, but nevertheless, these accounts of the experiments carried out and the developments achieved in this particular branch of industry have a direct interest to anyone interested in high temperature technology.

Typical of the papers presented is one on the ICI naphtha catalytic reforming process which produces town gas with a calorific value of 500 Btu/ft^3 more economically than processes based on the use of coal. The reformers used in this application operate at high pressures and high temperatures and the development of the necessary alloys to withstand the conditions of service, and the means to fabricate them, had to be determined before construction and operation was put in hand. With the aid of photographs, charts and diagrams the text outlines the application of the process; its chemical theory; the technological aspects of reforming; problems met due to corrosion, etc and the development of the use of the process since 1961.

Thirty-one papers are thus similarly presented and their range of interest embraces: pressure steam reforming; hydrocarbon processing; refractory concretes; secondary reformers; and the specific development of special steels and alloys, tubes, ceramic materials, refractory lined pipes and heat resisting rubber connections; together with details of experiments carried out to determine the cause of assembly failure, the effects of corrosion and other adverse factors.

The text of the papers is largely descriptive and does not demand a detailed knowledge of chemistry or chemical engineering experience in order to be comprehensible. Most of the papers give summaries of the inferences made and the conclusions determined during laboratory work by the authors who are variously employed in universities, ICI and other firms of international repute.

F.T.S.

PHOTOELASTIC ANALYSIS

By A. W. Hendry, PhD, DSc, MICE, MIStructE, FRSE
Professor of Civil Engineering, University of Edinburgh

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 17*s* 6*d*)

In spite of the ever increasing use of computers to solve the stress-distribution problems of designing engineers who wish to avoid protracted mathematical analysis, considerable research is being carried out to find the answers of these and other constructional problems by loading and testing small-scale models, particularly in those realms of construction hitherto unattempted for which none of the known design "yardsticks" are suitable for preliminary investigations.

An extension of the scaled-model technique is the photoelastic analysis, which is based on the quasi-crystalline behaviour of stressed transparent materials. This was first discovered by the physicist Brewster in 1816 when investigating the stresses in arches by optical methods, but it did not become a practical reality—in spite of later efforts by those nineteenth-century physicists Fresnel, Wertheim, Clerk, Maxwell, Mach, Kerr and Pockels to develop the theory of artificial double refraction—owing to the difficulties of cutting glass, then the only plastic material available, to the shapes required. Since that time the introduction of celluloid enabled Coker and Filon to produce their *Treatise on Photoelasticity*, and the development of other modern transparent plastics enabled physicists to analyse three-dimensional stress systems and put them to present day small-scale model use.

The text of this soft-covered book is primarily intended for engineers who are familiar with the elementary principles of elasticity and the theory expounded in chapter one, therefore, summarises the stress formulae and the theorems and definitions which are of particular importance in photo-elastic analysis. Thereafter, chapters are devoted to: the description of those optical phenomena which are related to the theory; the characteristic change of optically istropic plastics which, when stressed in the polariscope, exhibit certain features characteristic of crystals; descriptions of photo-elastic apparatus; instruments for measuring relative retardations; test procedures for two-dimensional photo-elasticity; the reduction of test data; the frozen stress method; coating and inserts; materials to use; and the practical applications of the theory.

An extensive bibliography of related literature is given at the end of the book.

F.T.S.

Technical Notes

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*, March 1966

INDUSTRIALIZED BUILDING. Great advances are being made in the techniques of industrialized building, and a landmark in this progress is the award of the first Appraisal Certificates by the National Building Agency. These certificates indicate that a system has been examined for structural safety, suitability, quality and durability, and has been deemed satisfactory on the basis of a sixty-year life. Twenty-nine industrialized systems have so far been awarded certificates, and these are listed by name.

BUILDING CONSTRUCTION ON SOFT ALLUVIUM. A very interesting article describes the use of Vibro-Replacement to stabilize an area of extremely poor ground in order to support a large new store building. Vibro-replacement is a process whereby stone "skeletons" are formed underground by the use of depth vibrators and selected granular fill material. As well as producing vertical "columns" of highly compacted material, the vibration process ensures that soft cohesive strata are locally displaced and replaced with an irregular compact granular fill. A cost comparison is made which shows that conventional piling would have cost 27*s* per square foot of floor area, against 12*s* for vibro-replacement. In both cases settlement is reduced to negligible proportions. A Floor Slab resting directly on the soft alluvium would have cost 8*s*, but settlement could be expected to exceed 18 in.

STEEL FIXINGS. A short article, with photographs, introduces two new types of steel fasteners that are being developed by the United Steel Corporation. One of these could have a military application in view of its speed of operation. It is a power-driven hammer which drives a specially designed nail through steel. It can be used to make structural connexions and could be an alternative to the bolt-gun for fixing demolition charges to steelwork.

C.F.R.

THE MILITARY ENGINEER

NOVEMBER–DECEMBER 1965

THE FOURTH SEACOAST by Major James M. Niel, Corps of Engineers. When the St Lawrence Seaway was officially opened on 26 June 1959, making the Great Lakes accessible to deep-draft vessels for the first time a Fourth Seacoast of the United States and Canada was created. This article is a condensed history of the progressive development of the rivers and canals connecting the Great Lakes with one another and the St Lawrence. A very clear picture of the essentials of the problems which were involved and the solution to them is given.

EARTHQUAKE STRUCTURAL DAMAGE by Jacob Field. The author is a leading consulting engineer in the United States. He investigated the conditions at Anchorage immediately after the 1964 earthquake on behalf of the US Air Force Directorate of Civil Engineering. The article broadly considers the factors governing the design of earthquake resisting structures pointing out how local geological conditions and local building practice affect the issue. It then goes on to a more detailed account of the damage inflicted at Anchorage with explanations of the structural factors behind the various failures. There are very good illustrations.

M4T6 SUSPENSION BRIDGE by Captain Richard L. Copeland, Corps of Engineers. A clear well illustrated account of how a company of engineers designed and built a 90 ft suspension bridge using M4T6 floating bridge components.

THE TRANSATLANTIC CABLE by Ensign Thomas A. Dames, Civil Engineer Corps, US Navy. A most interesting account of the various abortive attempts and the final successful laying of the first transatlantic cable. The centennial of this event will be celebrated in September of this year.

ENGINEERS AT THE WATER LINE by Colonel F. A. Gleason, Jr, Corps of Engineers. Swimming and deep-fording vehicles are included in Army equipment enabling units to cross water barriers without bridges or ferries. There are limitations however in entrance, water movement and exiting which the engineers must help to overcome. In this article the engineer tasks are stated in some detail and it becomes clear that amphibious vehicles, especially on a wide front, demand more engineering at the water line than ever before.

SUPER AIRPORT PLANNING by Rush F. Ziegenfelder and William W. Wilkinson. The rapid increase in the number of passengers travelling by air and the development of aircraft with ever increasing passenger capacity has led to reconsideration of the basic principles of airport design. In this article two ideas are described. The underlying idea of both of them is the separation of aircraft operations from ground transportation activity through the use of independent passenger terminals spaced in one case about a central terminal building. This system is called the satellite concept and is clearly described and illustrated. The other system the unit terminal is not so easy to understand from the description.

NUCLEAR REFUELLING TRAINING by Captain Charles H. Coates, Jr, Corps of Engineers. A short well illustrated account of the facilities for training refuelling crews at Fort Belvoir. The training is important as it shortens the time of shut down of a nuclear power plant and also lessens the radio active hazard.

DRY DOCK CONSTRUCTION AT PORTSMOUTH by Lieutenant James B. Sullivan, Civil Engineer Corps, US Navy. An interesting well illustrated account of the adaptation of an existing dry dock at the Naval Shipyard at Portsmouth (New Hampshire) to accommodate Polaris missile nuclear powered submarines. This involved deepening the dock from 17 to 37 ft and lengthening it by an additional 130 ft.

USAHOME by Colonel E. P. Yates, Corps of Engineers. USAHOME is the name of a prefabricated house designed to meet the requirements of American Military installations overseas. The houses are three and four bedroom units with net floor space of 1,062 to 1,310 square feet. The design allows for mass production methods being used and for packaging into a minimum volume. The design also allows for the great variety of sites and climates to be found in the various military stations. Erection time for a trained crew of twenty men is claimed to be one day plus two for final trim and finishing. The article is too short to give many details of design and construction but there are good photographs.

LOGISTICS OF PM-2A REMOVAL by Major L. E. McKinney, Corps of Engineers. PM-2A was the Army's first field nuclear power plant which was installed at Camp Century in Greenland in October 1960. It was decided in 1963 to operate Camp Century on a summer seasonal basis and to remove the PM-2A and transport it to the Thuke Air Base, 138 miles away across the ice-cap for return to the US. The disassembly and movement of an operating nuclear power plant had never before been attempted. Owing to the short time allowed by arctic weather conditions, April to September and the complicated nature of the work, which is brought out very clearly in the article, the operation was one of great logistical interest. Critical Path Method analysis was used to plan the operation which was, in fact, carried out ahead of schedule.

MILITARY ENGINEER FIELD NOTES

RAFTING OPERATIONS IN FAST WATER by 1st Lieutenant John B. Mumford, Corps of Engineers. A short account with clear diagrams of three different rafting techniques tried out using components of the Class 60 bridge in Germany.

RUBBLE OBSTACLES by Captain Roland F. Seylar, Corps of Engineers. Making rubble obstacles, which give a short delaying effect, is considered worth while and this article describes tests which have been carried out using the buildings of an abandoned town in Germany. Details of the methods used and charge calculations are given.

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SPECIAL LIMITED WARFARE EQUIPMENT by Colonel Frank J. Nemethy. This is a description of the work being done at the Army Limited War Laboratory at the Aberdeen Proving Ground, Maryland. The object of the Laboratory is to design and produce special equipment called for by the conditions of antiguerrilla warfare now known as counterinsurgency. Among other equipments described is a rifle sight to provide rapid sighting, smoke signalling devices, lowering systems by means of which personnel and cargo up to 500 pounds may be lowered with safety from hovering helicopters and a tree top platform for look out and co-operation with helicopters. Details and illustrations are given of the various equipments.

MILITARY AIR BASE-COMMUNITY PLANNING by Colonel Francis A. Sanders, Directorate of Civil Engineering, US Air Force. A very interesting account of the various factors which have to be taken into consideration when planning the construction or adaptation of an air base. The extent to which the local community is involved is clearly brought out. Measures to reduce the noise nuisance are described.

ARMY ENGINEERS IN VIETNAM by Maj-General T. J. Hayes, 111 Corps of Engineers. A very brief summary of the work being done by the Engineers in Vietnam. The principal work is the development of three virtually new ports and four air bases, at four enclaves which can be supplied by sea. This is additional to the usual engineer tasks such as maintaining communications which are under continual attack by Viet Cong.

OPERATIONS AT CAM RANH BAY by Captain Lindbergh Jones, Corps of Engineers. Cam Ranh Bay is one of the new port areas referred to in the article reviewed above. The main outlines of the work accomplished and in hand is given and there are interesting illustrations. The engineer effort being put into the Vietnam war is very impressive.

FREEWAY TO THE BEACH by J. J. Traffalis and J. J. Hromadik. This is a description with good illustrations of a causeway to provide a floating roadway from a LST to the beach. The current design consists of NL pontoon sections but the new design uses inflatable sections which allows for more to be carried side loaded in a LST. Ample details are given and trials have been successfully carried out.

LESSONS OF THE NORTH-EAST POWER FAILURE by Lloyd Anderson and Emil H. Rice. A short article which gives the reason for and the effects of the failure of the grid system supplying the eight north-eastern states of the US and Ontario Province in Canada. Military installations were able to remain operative thanks to the provision of reserve power units which is a source of satisfaction to the authors who are engineers in the North Atlantic Army Engineer Division.

ENGINEER AID IN THE WAKE OF HURRICANE BETSY by Colonel Thomas J. Bowen, Corps of Engineers. A well illustrated but brief account of the damage caused in Louisiana by hurricane Betsy and the measures taken to restore the *status quo*. Much of the work consisted in pumping vast quantities of water from the flooded areas inside the levees which are below sea level because most of the usual pumping plants were out of action.

SPACE AGE DRY DOCK by Comdr. Blake W. Van Leer, Civil Engineer Corps, US Navy and Ernest L. Dodson. This is a description of the design and construction of a dry dock at the Charleston Naval Shipyard, South Carolina, capable of taking two SSBN 608 Ethan Allen Class submarines. The dock at Portsmouth described in the November–December Number of the *Military Engineer* preceded this one in date of completion but was for only one vessel. Considerable detail of design and process of construction is given and the advantage of making the use of PERT a contract requirement is emphasized.

COMBAT ENGINEERS IN THE DOMINICAN REPUBLIC 1965 by Colonel H. F. Cameron, Jr, Corps of Engineers. An interesting article which gives a picture of the action and organization of the US forces sent to keep the peace in San Domingo. The engineer tasks are well described and follow the usual pattern. One particularly interesting feature was the provision, against the clock, of a floating POL discharge point.

THE SOO LOCKS by C. A. Aune. This is a detailed account of the construction of the locks which have been built and which are being built to improve the water communication between Lake Superior and the other Great Lakes. The article fills in some of the details omitted from "The Fourth Seacoast of the United States" which appeared in the November–December Number.

ICE ENGINEERING IN OPERATION POLAR STRIKE—ICE RUNWAYS by Captain James W. Dunmyer and ICE BRIDGES by Lieutenant William H. Smith, Corps of Engineers. During Operation Polar Strike, the winter manoeuvre held in central Alaska in January and February 1965, innovations in the use of ice for bridges and runways were made and led to its development as a serviceable material for military operations. These two articles describe the preparation and maintenance of a landing strip on the frozen surface of a lake and the construction of a bridge. Where the bridge was across the frozen surface of a running river, considerable reinforcement with logs and brushwood was found necessary.

IMPROVING POWER PLANT PERFORMANCE by Lieut-Comdr R. C. Clark, Civil Engineer Corps, US Navy. This is a detailed examination of why a power plant in a naval base was not achieving its designed-power output. The reasons were various including faults in location in respect to the prevailing wind, uneven distribution of cooling water, the system for cleaning the oil fuel was inadequate and so on. A very useful guide or series of hints as to what to look for if faced with a similar problem or with the design and installation of a power plant.

INFLATABLE DAMS. There is a short note with a photograph on page 57 of "Fabridams" flexible fabric dams which can be filled or emptied and which are being used to control the flow of the Jhelum River in connexion with the Mangla Dam project in Western Pakistan.

MILITARY ENGINEER FIELD NOTES

ANFO IN THE ARCTIC by Lieutenant Harold A. Froehle, Corps of Engineers. Almost every spring two large Alaskan rivers develop huge ice dams in their lower reaches causing extensive flooding to low-lying villages. This article describes the methods employed by the engineers to overcome the danger. The use of ANFO a mixture of ammonia nitrate and fuel oil is recommended as a cheap and efficient explosive. How to apply it is explained with illustrations.

AIRFIELD CLASSIFICATION by Captain Richard G. Adamski, Corps of Engineers. Runway length would seem to be the main consideration in classifying an airfield but runway soil strength may well be a more important factor in determining the types of aircraft for which an airfield is suitable. This note gives a suggested classification which is being considered by Army Engineers at Fort Belvoir. The four classes are Assault, Forward Area, Support and Rear Area. Each one capable of handling progressively larger aircraft.

J.S.W.S.